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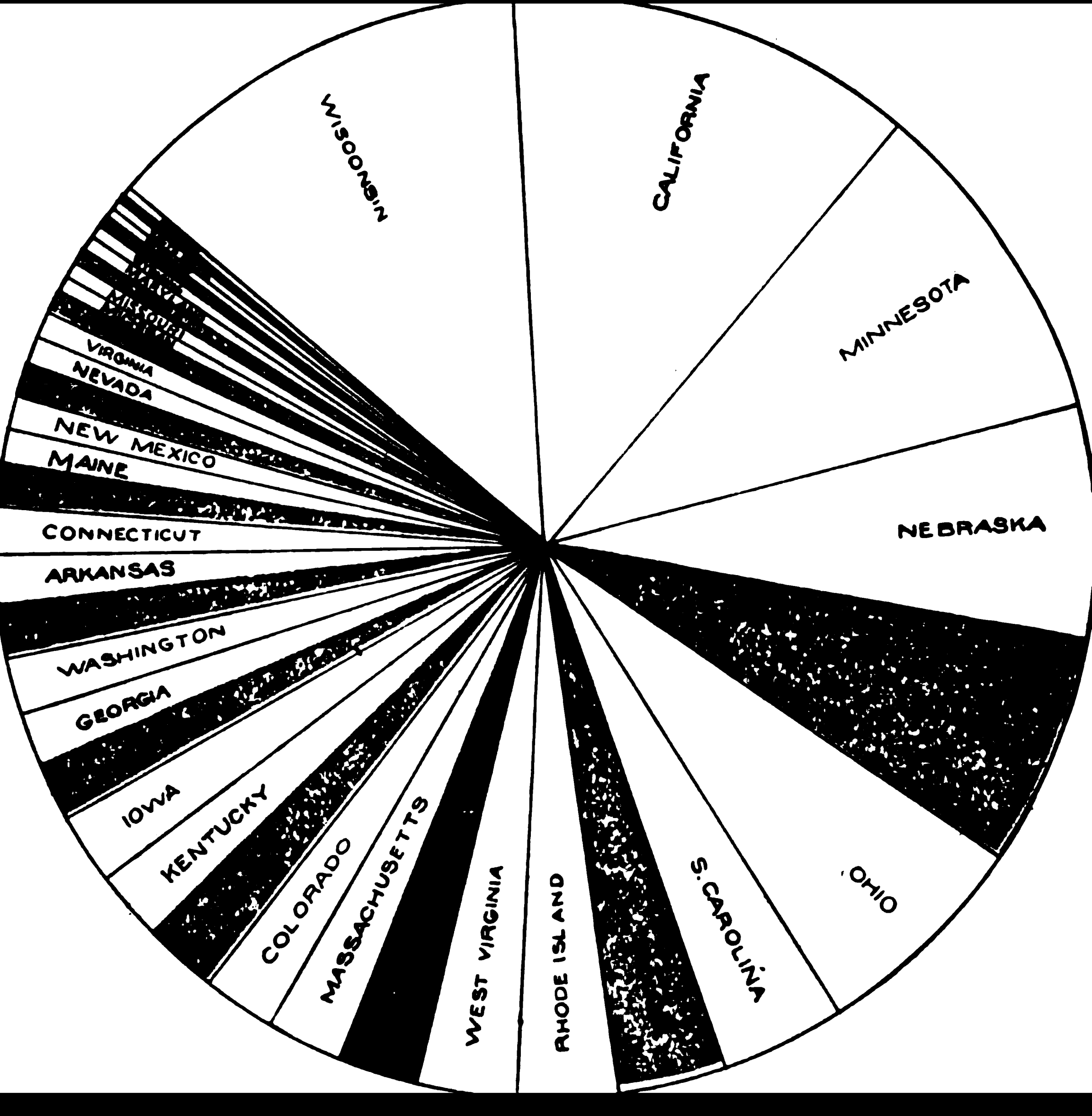

Report of the Pennsylvania State College for the year ...

Pennsylvania State College, Pennsylvania State College. Agricultural Experiment Station

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ANNUAL REPORT

OF THE

Pennsylvania State College

FOR THE YEAR 1897.

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Part I—DEPARTMENTS OF INSTRUCTION.
Part II—AGRICULTURAL EXPERIMENT STATION.

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CONTENTS OF PART I.

	Page.
Agriculture,	12-27
Biology,	28-9
Botany and Horticulture,	30-1
Chemistry,	32-9
Civil Engineering,	40-1
Electrical Engineering,	42-4
English and Rhetoric,	45-6
Experiment Station,	12-16
History,	47-8
Industrial Art,	50-1
Latin,	48-9
Library,	52-4
Mathematics,	55-6
Mechanical Engineering,	57-8
Military Department,	59-62
Mining Engineering,	63-7
Modern Languages,	68-9
Physical Education,	70-72
Physics,	73-7
President's Report,	1-7
Psychology and Ethics,	78-9
Statistics of Land Grant Colleges,	8-11
Sub-Freshman Class,	80-1
Treasurer's Report,	79-84

75386

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REPORT

OF THE

Pennsylvania State College,

FOR THE YEAR 1897.

Harrisburg, Pa., March 30, 1898.

To the Senate and House of Representatives of the Commonwealth of Pennsylvania:

I have the honor herewith to transmit the treasurer's report of the receipts and expenditures of the Pennsylvania State College, for the year 1897, as required by law; and in connection therewith, the reports of the president of the college, and of professors in charge of the departments of instruction. These reports contain matter of great interest to the people of the Commonwealth, and give ample evidence of the fact that the college is worthily fulfilling the ends for which it was established.

JAMES A. BEAVER,
President of the Board of Trustees.

I.—PRESIDENT'S REPORT.

To the Board of Trustees of The Pennsylvania State College:

Gentlemen:—I have the honor to present herewith my report for the year 1897, accompanied by those of professors in several of the departments of the College.

Few changes have been made in the list of Faculty and Instructors. During the summer Mr. F. H. Greenwood, B. S., Worcester (Mass.) Polytechnic, and Mr. Budd Frankinfield, B. S., E. E., Madison (Wisconsin) University, were appointed Instructor in Practical Mechanics, and Instructor in Electrical Engineering, respectively, in place of Mr. Charles Stone and Mr. H. A. Lardner, resigned. In October, Mr. Charles L. Griffin, B. S., Worcester (Mass). Polytechnic, was appointed Assistant Professor of Machine Design, in place of Assistant Professor Charles L. Heisler. Assistant Professor H. H. Stoek resigned his position late in November to accept a position on the staff of the Colliery Engineer at Scranton, Pa. His place has not yet been filled.

The total number of students is about the same as last year, being 352. The number entering the Freshman Class, including three who entered at the opening of the present session, was 102. This number is practically the same as that of the class entering in September, 1896, but the results of the Fall Session's work show a decided and marked gain over any previou year in the history of the Institution. Making a comparison with the two preceding years, which are the only ones in which the Freshman Class has begun with over 100 men:—In 1895-6. the year opened with 116 in the Freshman Class. By the opening of the Winter Session 38 had been dropped. Of these, 14 entered the Sub-Freshman Class, making a net loss of 24. In 1896-7, the number was 102 at the opening and 15 less at the close. Only one of the 15 who dropped out entered the Sub-Freshman Class, making the net loss 14. The present class opened with 99. Thirteen dropped out by the opening of the Winter Session, three of whom became Sub-Freshmen, thus making the net loss 10. Three new men entered at the opening of the Winter Session, making the class number 89. This is the largest number that any class in the College has ever had at the opening of the second session, and the general character of their work in College is exceedingly encouraging. A few have made advanced standing by passing examination in Solid Geometry; one, on entering, passed examination in all the mathematics of the Freshman and Sophomore Years; one other, at least, will probably make Junior standing early next year. This improvement in preparation is the more gratifying when it is remembered that there was no lowering of the standard of requirements, after the discouraging failure of so large a number in 1895-6. On the contrary, the pressure to secure thorough work has steadily increased notwithstanding the criticism from many influential quarters to which the College was subjected. We have abundant evidence that it would have been easy to secure a larger increase of numbers by lowering the real, if not the nominal, standard of admission to the Freshman Class. An increasing number of young men and young women in Pennsylvania are seeking a higher education. Many of them are deterred from taking a College course because of inability to spend the time and money required to pursue a preparatory course away from home, in addition to a four years' course in College. The consequence is that considerable numbers of them attempt to enter College with hasty and inadequate preparation, and then disappoint both themselves and their friends by their inability to maintain standing in a fair average of College work. It is to be expected that the movement just inaugurated for the establishment of township High Schools will, in time, work an important relief in this direction by enabling the youth of the rural districts to secure, in their own neighborhoods, the requisite preparation for a College course. In the meantime, it has been the policy of the College Faculty to admit provisionally, at the opening of the Fall Session, all those who gave evidence of having completed the required amount of preparatory study, except in cases of manifest deficiency in the quality of work done, and, in one class of cases, to admit students who had not thoroughly completed the entire amount of preparatory work, but who showed thoroughness of training, as far as they had gone, together with intellectual ability and earnestness of purpose. After the work of the year begins, every effort is made to give special assistance to those who need it and show a disposition to profit by it, and the standing regulations of the College are liberally devised, with a view to enabling every student to do the kind and amount of work which he is able to carry on, receiving both credit for any work which he may have already done in advance of his class standing and a proper allowance of time for making up deficiencies. In other words, while the College maintains its fixed standard of requirements for the completion of any of the regular courses, it aims more and more to open the way to *special courses* for those whose time or means does not justify them in seeking a diploma, or those who aim to work as specialists in any given direction.

It is an interesting fact, however, that there is a decided tendency among these irregular students to work into a regular course and ultimately to secure a diploma. Many a man who felt that he had means for but one year's College work has in this way been encouraged to struggle through four years and often with high credit. But, while thus making every possible concession to individual needs, the Faculty has, at the same time been solicitous to maintain such a standard of work in every department of the College, as will enable its graduates to take equal rank with the graduates of the best institutions elsewhere, and make its diploma, when once obtained, a badge of honorable distinction. In these days of keen and active competition in every department of life, the best accessible training is none too good. The field of modern knowledge is so wide and diversified that no person can claim to be fairly educated who is not conversant with at least the fundamental principles of many different branches of learning; and the relation of these different branches is so close and complex that no one can, as a rule, hope to attain eminence as a specialist who has not first laid a broad and sound general foundation. The policy thus indicated is, in my judgment, the only one which will insure for the State College a lasting and worthy success or justify its maintenance at public expense.

The experience of the last few years clearly shows that the Preparatory Schools of the State appreciate the work which the College is doing in this direction. They have, in many instances, modified their courses of instruction so as to enable their students to meet the College requirements and have found the character of these requirements a stimulus and aid in exacting a better quality of work. It can not be expected that the growth of the College, in numbers, will, at present, be so rapid as it might easily be with a lower and looser standard of requirements but, with lower and looser standards of requirements, its career as a technical institution would be short. On the other hand, it is each year attracting, and must continue to attract, an increasing number of those who are best qualified to take advantage of the opportunities which it affords them, and its growth will be secure and permanent in proportion to the excellence of its work.

The constituency of the College continues to cover well the whole State, 59 counties being represented this year. Ten other states are also represented.

The tone of student life is most creditable. It is doubtful whether many institutions can show an equally satisfactory record during the College year.

Greatly to the regret of all, it was found necessary, in the early part of the Fall Session, to dismiss four students for participation in hazing. The attitude of the Trustees and the Faculty toward this peculiarly unmanly and debasing form of offense had been explicitly stated to the student body and it was felt that young men whose sense of honor would not restrain them from it ought not to be tolerated as members of the College community. With this exception the general life of the College has been vigorous, wholesome, manly and loyal.

The interest of the student body in the various forms of athletic sport continues to show a healthy increase. The general influence of this spirit has been excellent, I believe, both physically and morally. There is always danger, on the part of some, of over exertion on the one hand, or a neglect of College duty proper, on the other hand; but the leaders in these sports among our students have, as a rule, steadily exerted themselves to prevent either of these abuses and the Faculty, while giving every encouragement to legitimate athletics, has insisted upon both regular membership of the College, and fair standing in class work, as an indispensable condition of participation in games away from the College.

The continuous, systematic work of the Physical Director must ultimately contribute much to the same end. The report of Dr. Newton indicates, to some extent, the great amount of careful labor and discrimination required for such a duty. Considerable time must necessarily elapse before marked results will be apparent, and it is to be regretted that the time of students is already so closely occupied with their various duties, including Military Drill, as to leave but little opportunity for special physical training. It is also becoming more apparent each year that this important branch of work can not be properly carried on without a gymnasium, to be used exclusively for that purpose. Up to the present time the Armory has been made to serve the double purpose of a gymnasium and drill hall, but the student body is now too large to admit of such use much longer.

For a somewhat detailed statement of the condition of the several Departments of College work, their standards, methods and results, I respectfully call the attention of the Board to the accompanying reports. The Executive Committee has exercised the greatest possible care to provide for the most urgent wants of each Department, but the field of our work has broadened so rapidly that each year brings new demands, in addition to the standing and important necessity of keeping up, in good condition, the equipment which we already possess, and the statements made in the several reports respecting present needs have my full concurrence and merit the most considerate attention of the Board.

Since the last meeting of the Board in Harrisburg, the State Senate has initiated a movement which is likely to have an important influence upon the future development of the College and its relation to the Commonwealth. It has long been apparent that the composition of the Board of Trustees, so far as relates to its elected members, no longer answers its original design, owing to a radical change in the conditions out of which that design grew. When the College was first established as a purely Agricultural School, the expectation of its founders was to draw its support principally, if not wholly, from the agricultural class, and to make the agricultural organizations of the State directly responsible for its management. To this end its elected members were to be chosen by the County and State Agricultural Societies, which were then the only organizations representing that great branch of industry. But the original designs were never fulfilled. Very few agricultural societies ever interested themselves in the management or work of the College and, of those few, a still smaller number maintained anything like continuous interest. Even if that result had not followed, a much more sweeping and far reaching departure from the ideas of the founders was brought about from two distinct causes: the practical disappearance of the agricultural societies in many portions of the State, or a change in their character, and the necessary broadening of the work of the College, in accordance with the Land Grant Act of 1862. In order to meet the requirements of that Act, several changes have been made in the charter of the College, but the elective members of the Board are still chosen by a convention of delegates from such agricultural societies as choose to appoint them. It need not be said that a convention so appointed is not a representative body in any true and proper sense; and, while it is even more desirable than ever before, if possible, that the agricultural interests of the State should be represented in the control of the College, it is eminently desirable and necessary that such control, in the case of a State institution, should involve a definite and effective responsibility to the State as a whole. The correctness of this view has been so fully recognized by the Board of Trustees, that at its meeting in January, 1895, it unanimously approved the draft of a bill providing for the appointment of Trustees by the Governor and the Senate, in the place of such as are now elected by the convention above named. By the same bill the number of ex-officio members of the Board was slightly reduced and the number of Alumni members slightly increased, but no change was made in the powers or duties of the Board, as thus to be constituted.

The bill passed the Senate with slight and unimportant modifications but failed in the House, on account of the overcrowded condition of the Calendar at the close of the session. At the session of 1897, the bill, in the form in which it had previously passed the Senate, was again introduced and seemed likely to pass, but a number of Senators were of opinion that, if any change was to be

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made in the organization and management of the College, such changes should be embodied in a comprehensive measure having regard to both the present condition and its future requirements. A committee of five Senators was accordingly appointed, with instructions to make a thorough inquiry into such matters as should guide the action of the Legislature and to report during the session then current. The committee made a visit to the College and began a preliminary inquiry, but found the interests involved to be so much larger than had been anticipated, and the questions to be settled, so important, as to preclude the possibility of making a satisfactory report within the time specified. The committee then asked and received authority to sit during the recess of the Legislature and to report at the next session. The character of the committee and the spirit in which it began its work give us good reason to believe that they will take a wise and comprehensive view of the place which the College holds, and may in the future still more largely hold, in the public school system of the State.

The degree of misunderstanding which exists in many portions of the State in respect to the work of the College itself and, especially, in respect to its relations to the State government, is surprising and well nigh incredible. The idea has been sedulously fostered in some quarters that the State College has no special claim upon the support of the State Treasury, and that appropriations made to it by the Legislature might, with equal justice, be made to other institutions. It seems not to be understood that the State of Pennsylvania has accepted a valuable gift from the United States and has pledged the faith of the State to administer that gift according to certain specific conditions. These conditions are clearly and explicitly stated in the Act of Congress of July 2, 1862, and were accepted without change or qualification and in the most unmistakable terms by the Legislature of Pennsylvania, in the Act approved April 1, 1863. For many years the State apparently lost sight of the solemn public obligations which it had assumed, but, when that fact once becomes clearly fixed in the mind of the Legislature and of the public generally I can not doubt that the interests of the State College will be cared for in a manner worthy of the State of Pennsylvania. In this matter the College has and can have no separate and individual interest. The question is not what shall the State of Pennsylvania do for the State College, but how shall she use the College in such a manner as best to fulfill her contract with the United States, and strengthen her own agencies for the promotion of public education.

I desire to call particular attention to the very interesting and instructive charts which Professor Reber has prepared for the purpose showing what use has been made of the United States Land Grant by the several States. I know of no other equally comprehensive presentation of this important subject, the salient points of which are briefly set forth in his accompanying discussion of the charts.

In conclusion, I desire to express my most grateful appreciation of the kindness of the Board in granting me a much needed period of rest, and my thanks to the Executive Committee, and to the Faculty, for their untiring and loyal oversight of the interests of the College during my absence.

Respectfully submitted,
GEO. W. ATHERTON

State College, Penna., March 19, 1898.

SOME STATISTICS OF THE LAND GRANT COLLEGES, WITH ILLUSTRATIVE CHARTS,

Prepared by Professor LOUIS E. REBER.

The accompanying charts present graphically certain data relating to the amount and sources of income and the expenditures of the Land Grant Colleges of the United States. They speak for themselves, and clearly show Pennsylvania's relations with her State College.

In order to bring out some further points it seems advisable to add the following facts, deduced, for the most part, from statistics tabulated by the National Department of Agriculture and the Commissioner of Education, and from information furnished by the institutions of which mention is made.

The National Government by the law of July 2, 1862, granted to "each state now existing and each new state admitted into the Union as many times 30,000 acres of public land as it had in 1860, or has at the time of its admission, representatives in both houses of Congress" for the establishment of what are now known as Land Grant Colleges.

In accordance with this act the Nation has thus far given about 13,000,000 acres, or 20,000 square miles of land.

The act of 1890 in order "To more completely endow the colleges established under the law of July 2, 1862," gave the sum of $15,000.00 to every State College and an increase of $1,000.00 annually till this sum should reach $25,000.00.

The great disparity which is shown in the charts in the amount of national aid received by the various states is to be accounted for less by the fact that different amounts of land were received, than by the differences in the management and disposal of the lands granted. Kansas, notably, though her grant was among the smallest (90,000 acres), has disposed of her land to such excellent advantage that she is in receipt of one of the best of the incomes derived from this source.

Our own State received 780,000 acres of land and has from this large grant an income of but $25,637.43.

New York received 990,000 acres of land and from this her university eventually realized $6,662,700.00, an average of $6.73 per acre. Had Pennsylvania disposed of her land at the same rate her State university would have received $5,249,000.00, instead of $439,186.00 (as was the case) and her annual income from this source would have been $314,964.00.

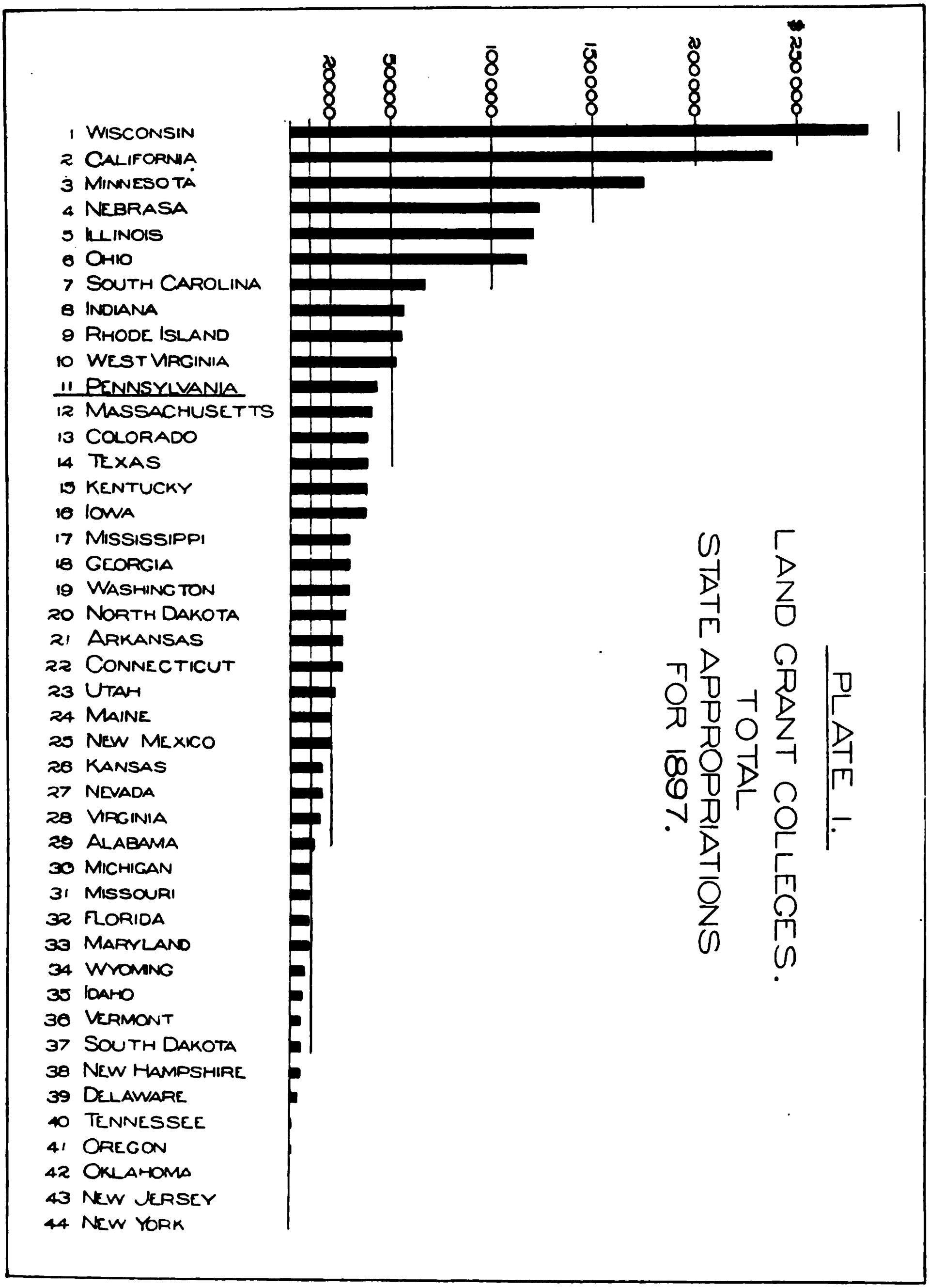
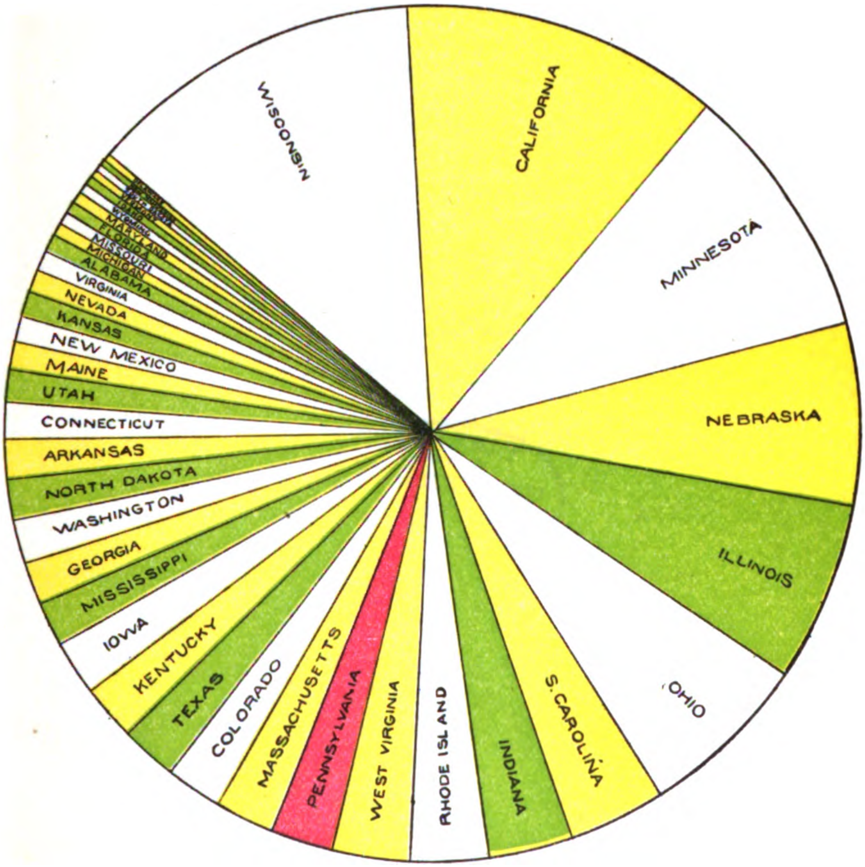


PLATE I.

LAND GRANT COLLEGES.
TOTAL
STATE APPROPRIATIONS
FOR 1897.

PLATE 2.

LAND GRANT COLLEGES.
TOTAL STATE APPROPRIATIONS FOR 1897.



AREA OF CIRCLE REPRESENTS TOTAL AMOUNT APPROPRIATED BY THIRTY NINE STATES. $1,771,000.

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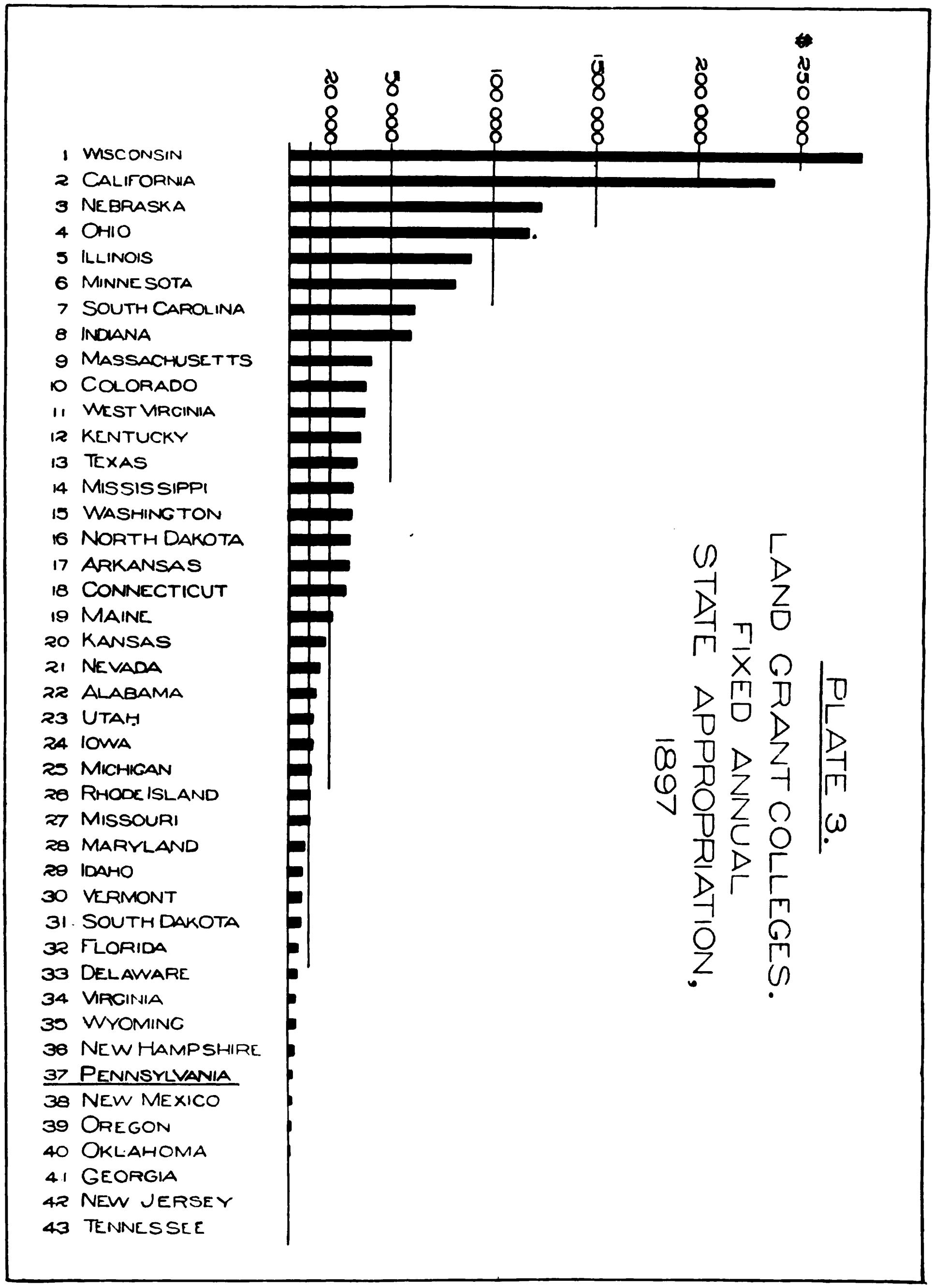

PLATE 3.

LAND GRANT COLLEGES.
FIXED ANNUAL
STATE APPROPRIATION,
1897

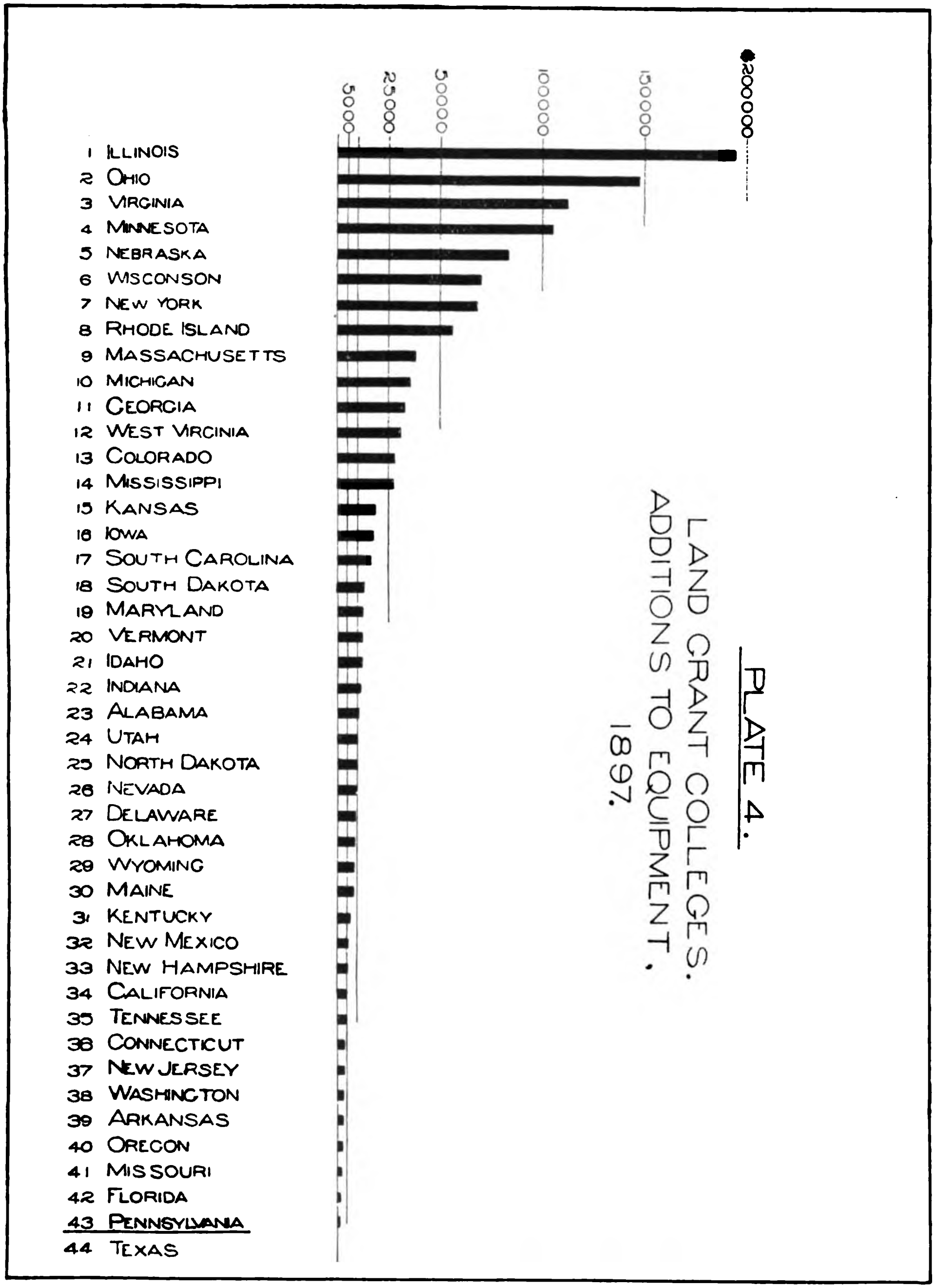

PLATE 4.

LAND GRANT COLLEGES.
ADDITIONS TO EQUIPMENT.
1897.

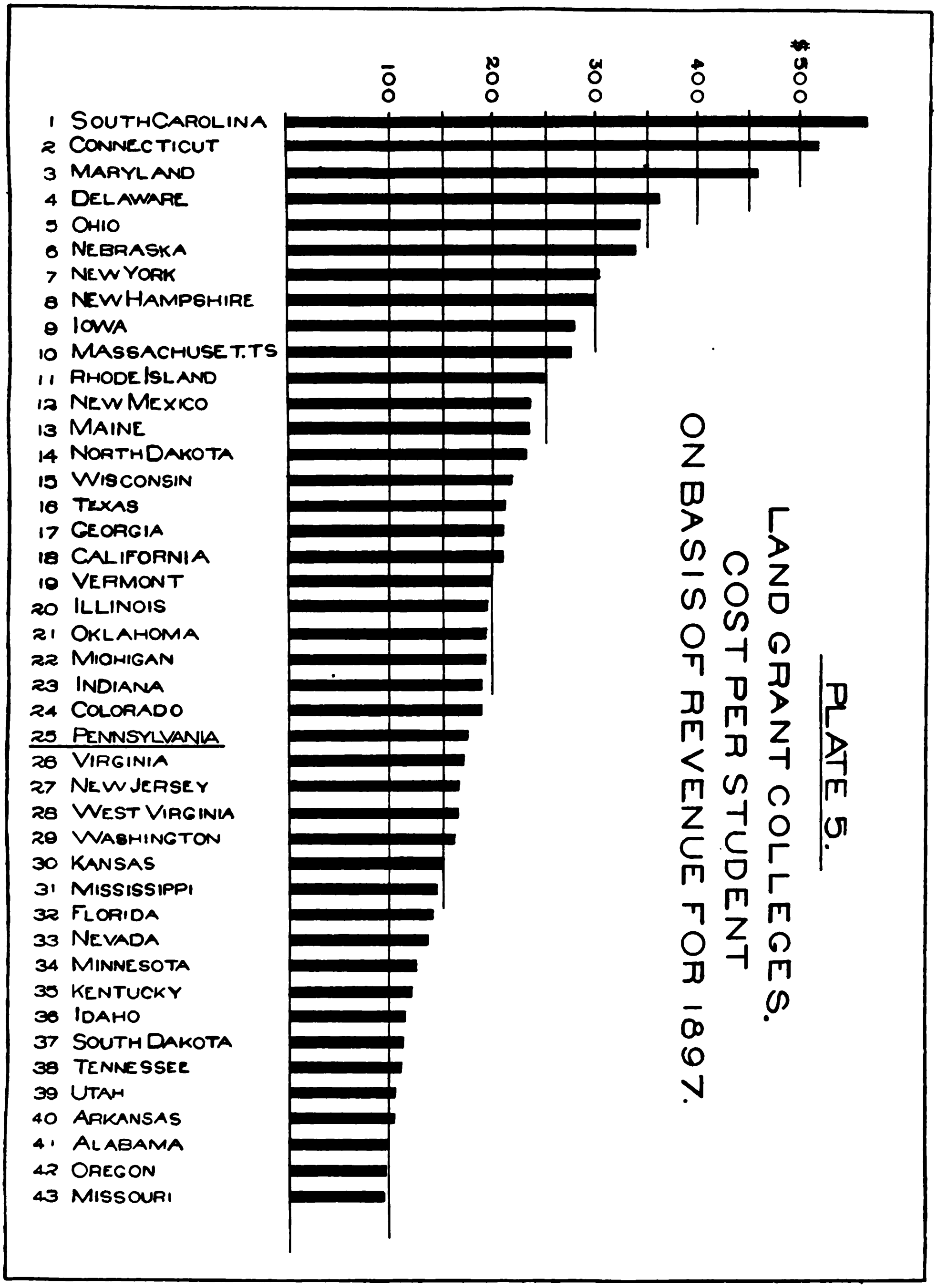

PLATE 5.

LAND GRANT COLLEGES.
COST PER STUDENT
ON BASIS OF REVENUE FOR 1897.

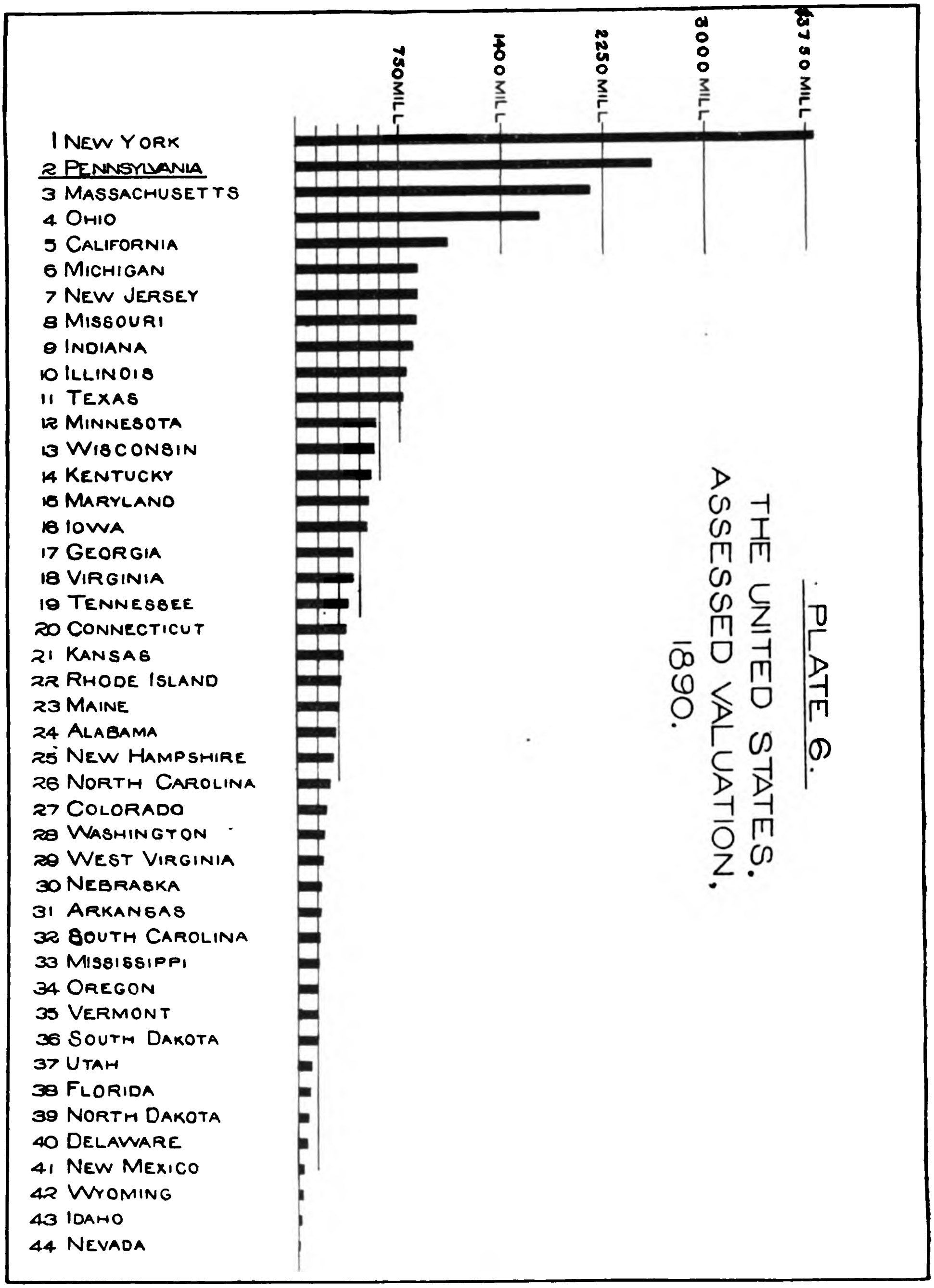

PLATE 6.

THE UNITED STATES.
ASSESSED VALUATION,
1890.

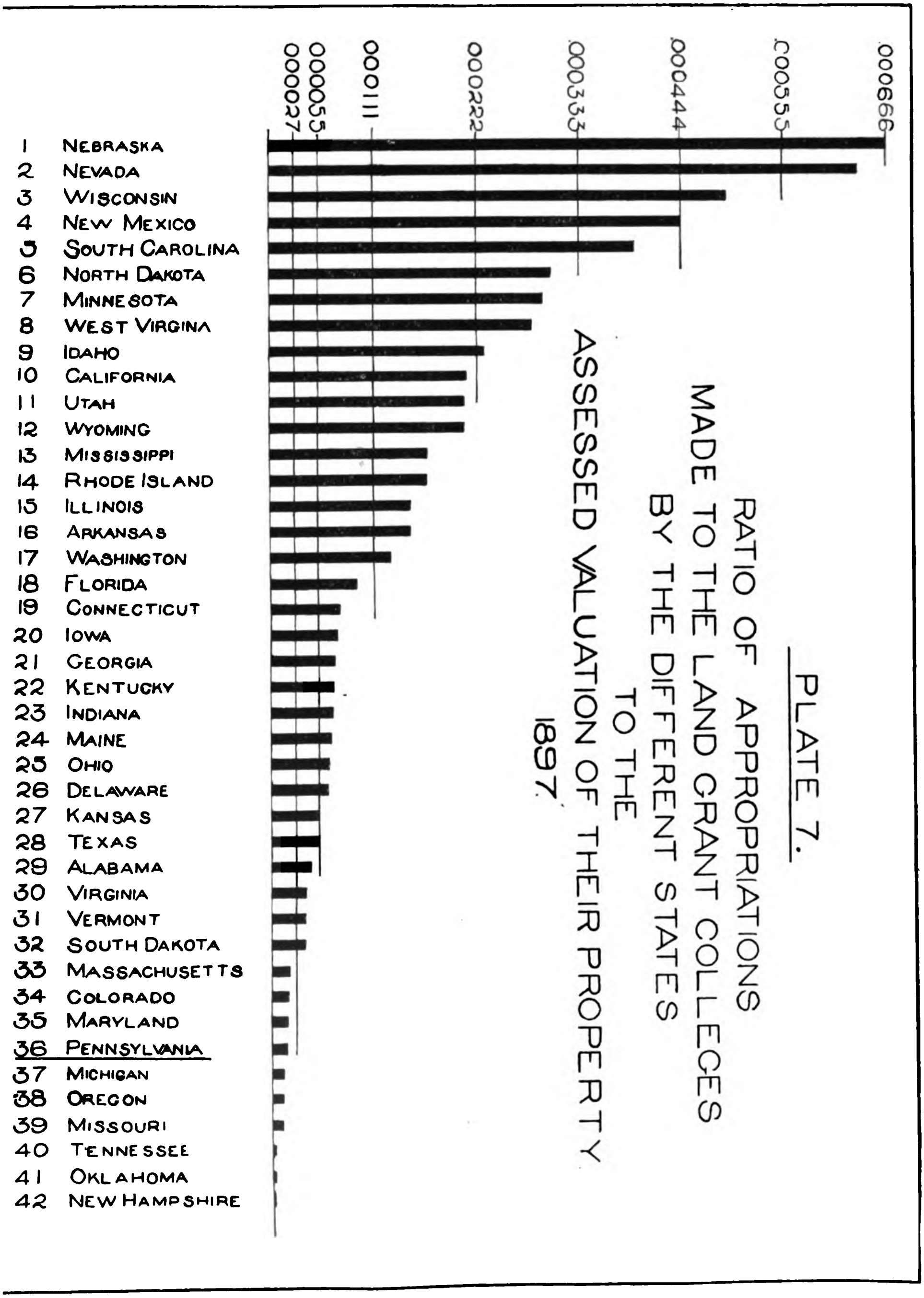

PLATE 7.

RATIO OF APPROPRIATIONS
MADE TO THE LAND GRANT COLLEGES
BY THE DIFFERENT STATES
TO THE
ASSESSED VALUATION OF THEIR PROPERTY
1897.

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The following figures further illustrate these differences:

Minnesota, with 120,000 acres, has an annual income of $27,410.00.

California, 150,000 acres, has an annual income of $43,619.33.

Iowa, 240,000 acres, annual income, $47,729.75.

Michigan, 240,000 acres, annual income, $31,450.00.

Kansas, 90,000 acres, annual income, $50,689.00.

Pennsylvania, 780,000 acres, annual income, $25,637.43.

At least thirty of the states disposed of their land to better advantage than did Pennsylvania—the most of them to much better advantage. This fact was appreciated and was brought to the attention of the Legislature by the Surveyor General in 1871, at which time the State government raised the endowment from $410,290.50 (proceeds of the sale of lands) to $500,000.00.

Colorado still holds a large part of her land grant. Missouri, too, holds a large amount of land (136,000 acres) and this with the condition that it shall not be sold for less than $7.00 an acre, whereby will eventually be added to her endowment not less than $952,000.00.

Statistics relating to the state of New York have been almost entirely omitted on account of the unique position of Cornell University among the Land Grant Colleges. She has reaped the benefit of the foresight and philanthropy of Ezra Cornell and others in so large a revenue that she has not (until recently, at least) desired state aid. Her trustees have evidently preferred being free to develop the university untrammeled by the state control which follows, and justly follows, state aid.

In those cases in which the land grants have been given to two institutions in a state, the sum of their incomes is charted. In Massachusetts for instance, a part of the fund goes to the Institute of Technology. Here, by the way, it must be remembered that an income is derived from tuition fees amounting, in 1897, to $215,000. Were it not for this item Massachusetts would stand eighth instead of second in annual revenue.

Attention must also be called to the fact that the University of Illinois had on hand at the end of the college year of 1895-96 a balance of $169,189, which was, in all probability, used for equipment. This would account for the fact that in chart No. 8 Illinois' line representing "equipment," is disproportionately long as compared with that representing total revenue.

The total value of the National appropriation for 1862 and 1890 is estimated by the Commissioner of Education to be $80,742,000.00. This figure was obtained by estimating the land value at the low average of $1.10 per acre and capitalizing the two National appropriations at the rate of 4 per cent. for the year 1897. The result is true only for the year 1897, since the appropriation of 1890 has not yet reached its maxim.

Many of the states, recognizing the munificence of the National government in appropriating so large a sum in the interest of higher education, have ratified their acceptance of the obligation to carry on successfully what the Nation has begun, by laying a definite tax for this purpose. This tax yields in all cases a maintainance fund only, provision for buildings being made by special appropriation. Other states have assured maintainance to their state institutions by making a fixed annual appropriation.

Thirty-nine of the Land Grant Colleges have in one way or the other secured definite annual state aid. Their relative rank in this particular is shown in charts 3 and 9.

The state of California has given its university over 2,000,000 acres of land, from which is realized $109,000.00 annually. From a fixed state tax (1-10 mill) the university received in 1897, $128,415.16. These amounts, together with a special appropriation made by Legislature, added to those received from the National appropriations, gave her in 1897 an income of over $300,000.00. In 1898 and thereafter this income will be increased, the fixed state tax of 1-10 of a mill having been changed to 2-10 of a mill. This magnificent provision is independent of special appropriations in which, also, the state of California has been extremely liberal.

Minnesota gives 23-100 of a mill annually. Colorado gives 6-10 of a mill. Wisconsin divides the tax for her university, giving a certain millage for administrative expenditure, other millage for general instruction and one per cent. of the railroad tax to the School of Engineering. Her total tax receipts for the state university were, in 1897, $283,000.00.

Ohio's millage (1-10) gives at the present time over $177,000.00, though the amount shown on the chart is only $118,900.00. This discrepancy is due to the fact that the annual tax rate for the university was increased in January, 1897, and the sum charted is for the college year 1896 and 1897. Nebraska had at one time a millage which yielded an income to the University of $170,000.00.

Let a comparison be made of the sums that would produce these annual incomes. Capitalizing at 4 per cent., Wisconsin's fixed income is equivalent to that accruing from an amount of over $8,000,000.00; California's of over $7,500,000.00; Ohio's of about $4,250,000.00; Minnesota's of nearly $4,000,000.00, and continuing thus, Pennsylvania stands twentieth, and this position is secured to her almost solely by her National revenue, her fixed income outside of this being only $5,382.00 a year.

The permanent growth of an institution depends in a large measure upon its fixed annual income. The question then arises, what has Pennsylvania done to secure such permanent growth to the Pennsylvania State College? How has she met the trust reposed in her by the National Government in the grants of 1862 and 1890?

The greater the resources of a State the more should she do for education and the more easily can she meet her obligations in this direction. Pennsylvania with an assessed valuation of $2,659,796,909.00, is almost $500,000,000.00 richer than any other state in the Union, except New York. Yet, though first in wealth (if we continue to omit New York) she stands thirty-sixth in point of liberality to her State institution.

II.—AGRICULTURE.

A—EXPERIMENT STATION.

To the President:

Sir:—I beg to submit herewith my report upon the operations of the Agricultural Experiment Station for the year 1897 and also some general considerations regarding the work of the School of Agriculture for the same period.

Experiment Station.

While there has necessarily been little or no enlargement of its scope, the work of the Experiment Station has gone steadily forward during the year and, if we may judge from the tenor of correspondence and the demand for publications, to the increasing acceptance of the public.

In my last annual report, I indicated three general lines of Station activity, namely: 1. Soils & Fertilizers; 2, Horticulture; 3, Dairy Husbandry. During the past year, the work of the Station has been grouped a little more distinctly about these three lines, although the income of the Station has not been sufficient to allow the work to be extended in proportion to the importance of these interests to the Commonwealth.

Soils and Feritlizers.—Under this heading, including also crops, the most prominent work of the Station, so far as amount of time occupied is concerned, has been the analysis of commercial fertilizers. This work, as in former years, has been done under contract with the State Department of Agriculture, the Department being responsible for the administration of the law and the selection of samples of fertilizers, while the Station has performed the analytical work. By the co-operation of these two agencies, the farmers of Pennsylvania are very thoroughly protected against fraud in the manufacture and sale of these important substances. Every brand of fertilizer sold in the State is analyzed, some of them several times, and the results are published and freely distributed for the information of all concerned. If a Pennsylvania farmer is defrauded in the purchase of his fertilizers it is not because all necessary information regarding its quality is not abundantly provided by the State.

During the year, the usual number of tests of varieties of agricultural crops has been made. The results of these tests were promptly and widely distributed by means of newspaper bulletins and a fuller discussion of them has been made in Bulletin No. 39, now in the printer's hands. They show a very marked difference in productivity in different varieties of wheat, oats and potatoes, and emphasize anew the fact that intelligent selection among varieties of plants is of just as great importance to the farmer as intelligent selection among breeds and strains of domestic animals.

The experiments with the several ingredients of commercial fertilizers, singly and combined, upon a rotation of standard crops have been continued upon the same plan as heretofore. These experiments are now entering upon their eighteenth year and, so far as I know, cover a longer period of time than any similar experiments in this country.

The subject of the domestic production of sugar has recently attracted renewed attention, particularly with reference to the culture of the sugar beet. At the suggestion of the United States Department of Agriculture, co-operative experiments were undertaken in various parts of the State, the Department furnishing a supply of genuine seed and also appointing the Director of the Station a special agent of the Department for the investigation, thus giving the Station authority to use the franks of the Department for shipping samples to it for analysis. The records of nearly seventy specimens analyzed in this laboratory and that of the Department at Washington show a very good average of quality and give every encouragement for further investigation into the capabilities of Pennsylvania as a sugar-producing State.

The experiments upon the culture of tobacco which have been carried on for several years past in Lancaster county have been continued under the same arrangement as for the two preceding years, namely, as a part of the work of the State Department of Agriculture under the immediate direction of the Experiment Station. Through the generosity of the same Department, similar work has also been continued in Bradford county.

Horticulture.—Besides tests of varieties of small fruits and other minor horticultural experiments at the College, the main work in horticulture has been an investigation of the apple industry of Pennsylvania, similar to the study of the peach industry whose results were published in Bulletin No. 37 and in the annual report for 1896. Owing to the demands upon the Horticulturist for teaching work during the Fall, and his detail to the farmers' institutes during the winter, it has not yet been possible to prepare a report upon this investigation.

Dairy Husbandry.—The experiments upon the maintenance feeding of mature steers which have been in progress since 1892, and which were designed to secure data as to one of the fundamental questions of stock-feeding, were continued during the first three months of 1897. The accumulated results of four season's work upon this subject, together with a complete summary of all similar work so far as known, are now being prepared for publication. An experiment upon the feeding of milch cows, designed to test the relative value of a narrow compared with a wide nutritive ratio was carried out during the early part of the year. The conditions of the experiment were to all appearance unusually satisfactory but the results were such as to make a repetition of the experiment seem desirable. A second experiment has therefore been inaugurated as a check upon the results of the first and both will be reported together at a later date. An experiment designed to compare the value of two rather new feeds in our markets, namely, cerealine feed and dried brewers' grains, with that of buckwheat middlings, was carried on parallel with the experiment previously mentioned and the results are now nearly ready for publication.

In addition to feeding experiments, a number of tests of hand separators have been made, some investigations into the keeping qualities of milk have been carried out, and also some interesting tests in dairy practice, of which may be mentioned particularly the use of pure cultures in butter-making, and the pasteurizing of cream for butter-making, the last named experiment being still in progress.

Limitations of Station Work.—From the day of its establishment, the Station has consistently maintained that its only hope of permanent success lay in specialization—in doing a few things well. Experimentation in agriculture, to yield results of any real value, must be done under absolutely comparable conditions and must take account of all the many influences which may affect its results. In other words, while practical in its aims, it must be scientific in its methods. Such experimenting is expensive. Consequently the Station has not entered upon many lines of work which would unquestionably be of great value to the State, simply because it has not had the means to do the work properly. Even the comparatively few lines which it has taken up are capable of a much broader development than we have yet been able to give them. Thus, a broad, general study of the soils of the State and their agricultural capabilities is a very urgent need which the Station at present has no means of meeting except by dropping other equally important lines of work. Similarly, the very important horticultural capabilities of the State should be the subject of an extensive and careful investigation. As already stated, the Station has made a beginning in this direction but at present can move but slowly in the matter. In many other directions it is compelled to do practically nothing. Thus, the very important subjects of market gardening and floriculture are scarcely touched at all by the work of the Station. The production of eggs and poultry in the State is estimated to be little if at all inferior to that of dairy products, yet not only has this important subject not been taken up to any extent by this Station, but the same is true of nearly every other Station in the country, there being but two or three exceptions. The subjects of entomology, as related to useful and injurious insects, and of the fungous diseases of plants, both of which cause enormous losses to the farmer, we are at present not prepared to study and the same is true of the parallel subject of the diseases of animals.

Another point to which attention may very properly be called in this connection is suggested by some of the statements already made. It will perhaps have been noticed that in several cases the results of experiments made nearly a year ago are not yet prepared for publication. The proper reduction and comparison of the results of an extensive experiment involves a large amount of clerical work which is not apparent in the published report. The time and strength of members of the Station force have been so fully taken up by the experimental work and their College duties that it has been impossible to carry on in addition this large amount of clerical and computing work as rapidly as is desirable. To make the results of Experiment Station work promptly available, increased clerical force is almost imperative.

The Future of the Station.—In my last report, I pointed out that the income of the Station was derived from the bounty of the United States and from the funds which it earns, chiefly by the analysis of commercial fertilizers, and that the State had made no appropriation for the current work of the Experiment Station. There appears to be no present probability that the income of the Station from either of the above sources will be largely increased in the immediate future. If this is the case, it is obvious that the work cannot be expanded to meet the increasing demands upon it. Undoubtedly the Station can do much work that will be of great value to the farming interests of the State if maintained upon its present basis, but with all these other lines of work opening before it and with the possibilities of material benefit to the agricultural interests of the Commonwealth which they present, it seems high time that the State should seriously consider the question of its policy toward its Experiment Station and should determine whether it will ask its farmers to be satisfied with the present provision for experiments in their interest or will supplement it by its own bounty. There can certainly be no question that a broad and liberal policy in this respect would yield a thousand-fold return to the material interests of the Commonwealth.

Publications.—The demand for the reports and bulletins of the Station is steadily increasing, especially as a result of the presentation of its work at the farmers' institutes. During the past year, at least five thousand names have been adde to the mailing list, which now amounts to about twenty thousand names; an average of seventeen requests for publications has been received daily since early in December. To supply this demand, the State prints eight thousand copies of the annual report of the Station, together with another eight thousand for the members of the Senate and House of Representatives, or sixteen thousand in all for distribution. The Station has been able hitherto to secure considerable numbers of reports from the quotas of members of the Legislature, but even were the whole number printed at its disposal, it would be insufficient to supply the demand. The State make no provision whatever for the publication of the bulletins of the Station, which it prints at its own expense. The cost of these in the large editions required is a very considerable drain upon the income of the Station. During the last session of the Legislature, an effort was made to secure the printing of these bulletins as public documents and also an increase in the number of annual reports printed, but both propositions were negatived and as a consequence the Station has been obliged to refuse a large number of requests for its annual reports. It is most earnestly to be hoped that provision will be made by the State at an early day for the printing of information which is obtained and distributed at no expense to the Commonwealth.

The School of Agriculture.

The interest in the agricultural courses of the College shows a steady and healthful growth. The most important, although not the most striking feature, is the increase of students in the Collegiate Course, in which seventeen are now enrolled, classified as one graduate, four seniors, six juniors, three sophomores, three freshmen and one special. In addition, five students in the "Special Course" are taking more or less of the studies of the collegiate course, thus making a total of twenty-three agricultural students in attendance at the present time. This number in itself is not large, but when we consider that until within a few years this course has seldom had more than one or two students and often none, it is evident that young men in Pennsylvania, as in other States, are coming to realize that thorough training is as necessary in farming as in any other business. This is a most encouraging feature. The entrance upon this occupation of even a few thoroughly trained men each year will be a powerful force in uplifting the status of farmers generally and the College can do no greater service to the State than to train such men. From every point of view, the growth of this course should be encouraged.

The Dairy Courses continue to be numerically the most popular. Last year thirty-nine students were in attendance upon the Creamery Course and several were refused admission on account of lack of room. For the year 1898, seventy-one applications, several of them very urgent, have been registered for the forty places open. This year, for the first time, it has been possible to add a course of six weeks in cheese-making, to begin February 16th. This has been limited to thirty members and there are already numerous applicants for it, with every indication that it will be full. While these courses cannot furnish much real mental training or education in any broad sense, they are proving themselves of great practical value in their own line. There is a large demand for young men who have taken these courses and there is no question that they will be a great aid to the improvement of the dairy industry of the State.

The so-called "Short Course" offers less immediate prospect to its students of financial returns and probably for this reason has been less popular. Seventeen students were in attendance during the first three months of this year. The commencement of this course in 1898 has been necessarily postponed to March 2d on account of the asbence of instructors at farmers' institutes, and at present the enrollment is small.

All the above lines of work have been seriously hampered by lack of proper facilities. This is especially the case in the creamery and cheese-making courses. The small creamery building now in use was constructed for an entirely different purpose. By means of several alterations it has been made to do passable service for instructional purposes so far as its limited capacity would permit, although it is not well adapted to the purpose. Its small size, however, has compelled us to limit the number of students who can be admitted to these courses, and while this number has been made as large as could possibly be accommodated, the demand has so largely increased, as already stated, that the applicants this year were nearly twice as many as could be accommodated. This matter was laid before the last Legislature and an earnest effort made to secure an appropriation for a suitable building for this very flourishing branch of our work, but without success. The only thing that can be done for the present is to continue the courses with as many students as can be accommodated, in the hope that more ample accommodations may be secured later.

While a creamery building is perhaps the most urgent need of this Department, additional accommodations are very much needed in other directions, in particular lecture rooms, laboratories, and museum accommodations. All the work of the Department with the exception of its creamery work is now carried on in a rough temporary frame building erected for the purpose two years ago. This building contains but two lecture rooms, capable of seating comfortably about twenty-five students each, a small chemical laboratory, and a fourth room serving the double purpose of a museum and a bacteriological laboratory. With the increase in the number of exercises resulting from the growth of the collegiate course, and with the large numbers to be accommodated every year in the creamery course, both the lecture room and laboratory accommodations are quite inadequate. During the short course, the small chemical laboratory available was fully occupied by the students of the collegiate course and by those of the short course who had laboratory practice in chemistry. As a result, the milk-testing work of the creamery class had to be done in a poorly lighted cellar room of the Experiment Station about 16 by 18 feet, into which were crowded a dozen or more men twice daily. The laboratory instruction in bacteriology, as already noted, is now given in a room in the temporary agricultural building which is also partially occupied as a museum. The location is exceedingly unsatisfactory and the fittings inadequate, while at the same time a not inconsiderable amount of valuable museum material is scattered about as room can be found for it in various parts of this and the Experiment Station building.

In addition to the pressure for room, the growing work of agricultural instruction has made severe demands upon the time and strength of the instructors, particularly when combined with calls for work at the farmers' institutes. If the work of the Department is to develop as it ought, it will be necessary in the near future to provide additional instructional force in certain directions.

One of the most important and promising features of the work of agricultural instruction at the present time is the Chautauqua Course of Home Study. There are something like 400,000 farmers in the State of Pennsylvania. But an infinitesmal proportion of these can come to the College for any course, even the shortest, while at the same time it is of the greatest importance to the Commonwealth that this large body of producers should carry on their business intelligently and successfully. While even a comparatively small number of graduates from one or the other of the agricultural courses may do much to diffuse information among the farmers of the State, it is nevertheless highly important that the latter, and especially their children, should be given some opportunity for direct agricultural study. This, indeed, rather than the education of the small fraction who can attend college, is the real problem of agricultural education at the present time. The public school system of the State affords, in the vast majority of cases, practically no help, and even should the study of natural science become general, it is, in my judgment, impracticable for the public schools to teach technical agriculture. The Chautauqua Course is an effort to supply this need, as far as may be, by lending the aid of the College to supplement the efforts of those farmers who desire to study the principles of their calling. It is conducted upon the well-known Chautauqua plan inaugurated by Bishop Vincent and has been too fully explained in previous reports to need further description here. During the past year, this Course has shown substantial progress. In particular, I desire to call attention to the lesson sheets which have been prepared and sent out by the Superintendent, as explained in his report. The results of this measure have been highly satisfactory in giving definiteness to the work, and the demand for them, as well as the faithful work done upon them by students and the excellent examination papers received, has shown that they supplied a conscious need.

But while the growth of this course is very gratifying, it presents, as was early foreseen, serious problems. At the present rate of growth, the necessary work seriously threatens to swamp our present facilities. Moreover, the lesson sheets have been prepared for only a few books of the course and the demands upon the members of the school in other directions are such that it is very difficult for them to find time for preparing additional ones, although all recognize the desirability of extending the system. Moreover, even with the present rate of growth, the amount of clerical work involved is becoming more and more burdensome. This course gives promise of being one of the most important forms of educational work inaugurated by the College, but, in order that it should succeed, special and liberal provision should be made at the earliest possible moment for pushing the work. In particular, provision is needed for the preparation of lesson sheets upon additional books of the course, for the clerical assitance necessary in handling the routine work, and for assistance in reading and grading examination papers.

As in previous years, members of the school have taken an active part in the work of the farmers' institutes. The aim of these institutes is to bring to the farmers in all sections of the State the most approved results of practical experience, as well as the results and conclusions of scientific investigation and experiment. It is altogether appropriate that members of the School of Agriculture should take an active part in the institute work and particularly in this latter feature of it. This has been very cordially recognized by the Director of Institutes, the Hon. Jno. Hamilton, and at his request representatives of the College have for the past two years accompanied each of the several corps of institute workers. During the early months of the year, two members of our force, namely, Dr. Wm. Frear and Mr. E. H. Hess, were thus engaged, while Mr. J. F. McCormick, a graduate of the College, although not in the agricultural course, accompanied a third section. At pres-

Wm. Frear, Asst. Prof. G. C. Butz, Mr. J. A. Fries, and Mr. E. H. Hess. Wm. Frear, Prof. G. C. Butz, Mr. J. A. Fries, and Mr. E. E. Hess. The detail of so large a number of men has resulted in a considerable increase of work for those remaining at home and also has necessitated the postponement of the opening of the Short Course in Agriculture to near the close of the institute season. These inconveniences have been cheerfully borne in view of the importance of the work, but, at the same time, it ought to be made possible for the State to utilize the resources of the College in the institutes without at the same time seriously interfering with its ordinary work. If, as seems entirely appropriate, the College is to continue to take an active part in the work of the farmers' institutes, this fact should be recognized in the appropriations made for its work and by the employment of additional instructors.

In conclusion, to sum up the situation in a single word, the limiting condition upon the work in agriculture, both experimental and instructional, at the present time is the financial condition. Opportunities for work of the utmost importance are opening before us in all directions and the question simply is how far means can be secured to take advantage of these golden opportunities.

Respectfully submitted,
H. P. ARMSBY,
Director and Dean.

State College, Penna., December 23, 1897.

B—AGRICULTURE.

To the President:

Sir:—I have the honor to transmit herewith the report of the Agricultural Department.

The work of instruction in this Department has been carried on practically on the same lines as in the previous year. Some new apparatus has been provided which increases materially the facilities for instruction, particularly in practicum work. The experimental work has consisted largely in carrying out the well matured plans of previous years. As much of this work was planned for a long series of years, immediate results were of comparatively little value; but as the years go by the data thus accumulated becomes of the utmost importance, not only to the practical agriculturist but to the instructor as well. To further extend this work and carry it out more fully, a considerable expenditure for building and apparatus is required. This is especially important in certain lines of agricultural work that have heretofore received almost no recognition from experiment stations and agricultural colleges. Without doubt the poultry industry of the State ranks second, if not equal, to the importance of the dairy products. This great industry heretofore has received little recognition. Other institutions are preparing to meet this demand both in an educational and experimental way. Should The Pennsylvania State College maintain its present creditable position in this regard, or even assume a position as leader in this one of the greatest fields of work, new buildings and modern appliances should be provided at an early date. One of the greatest needs of the Department is the erection of a permanent building with modern appliances for the use of incubators and brooders, which have become as important in the poultry business as separators and butter makers in the modern creamery. Not only have these appliances become relatively important in this industry, but of great importance to the agricultural interest of the State when profits and gross returns are considered.

The number of students taking the Four Years' Course in Agriculture is greater than at any previous time, which may be interpreted to indicate an appreciation of the Agricultural Course at The Pennsylvania State College and also an increased demand by agriculturists for a college education.

During the past year important changes and additions have been made in the Chautauqua Course. As has been the custom for several years, the list of books used in this Course is revised annually in order that the best available books may be placed before our students at the lowest possible cost. While this practice necessarily brings some slight confusion, yet in no other way has the Department been able to place the best modern thought before the students in agriculture. The increasing demand from year to year for additional help has necessitated the issuing of lessons to this great class of home students. During the past year sixty lessons have been prepared on the subjects covered by seven books used in the Course and other lessons are in the course of preparation. Each lesson constitutes about five pages of typewritten matter designed to bring the subject treated of in the book up to date, to offer suggestions for study and experimentation and to give page reference to the book on the subject in question. Each lesson is accompanied by a question sheet, to which questions the students are required to write out answers and send them to the Superintendent of the Course before the second lesson is sent. If the answers are satisfactory the second lesson is sent at once.

The following lesson on "Tile Drainage," to be used in connection with "Tile Drainage," by Chamberlain, will serve to show the manner in which the subject matter in question is treated in these lessons.

"THE PENNSYLVANIA STATE COLLEGE.

Chautauqua Course of Home Study in Agriculture.

Lesson No. 1, "TILE DRAINAGE."

The Theory.

The practice of removing surplus water from the land was practiced at a very early time, but not until comparatively recent times do we have records of anything like systematic drainage. The early drainage was undoubtedly for the improvement of sanitary conditions and for the removal of surface water.

About one hundred years ago systematic drainage was attempted in England for the removal of both surface water and stagnant water within the soil. This met with success and general favor and may be said to mark the beginning of modern drainage.

While many good effects of drainage have been known for a long time, yet many important results were wholly overlooked by those who may well be called pioneers in modern drainage. That surplus water should be removed

To make the soil mellow,
To make the soil warm,
To make the soil fertile,
To lengthen the season of cultivation,
To enable plants to better withstand drouth,

are some of the phases of drainage that have been studied most in recent times.

A superabundance of water in the soil is detrimental to plant growth for the following reasons:

1. It excludes air.
2. It absorbs heat.
3. It prevents chemical action from making the plant food available.
4. It delays cultivation.
5. It causes winter killing or heaving of crops,
6. It increases the ill effects of drouth.

1. A certain amount of water is necessary for the germination of seeds. Seeds in germination use or absorb oxygen and generate considerable heat. Soil from which the air is excluded can not fur-

nish the necessary oxygen for germination. (See "Plant Life on the Farm," page 77.) Roots of plants need air. (See "Tile Drainage," pages 9-10.)

2. A wet soil is a cold soil. The only means of warming a wet soil is by applying heat at the surface. This heat applied at the surface will evaporate water, which, in turn, is a cooling process. To remove surplus water by evaporation is not only a slow process but uses up a vast amount of heat that should be utilized by growing crops. (See "Tile Drainage," pages 17-18.

3. In nearly all arable soils there is a large amount of plant food that can be made available by cultivation, and the admission of heat and air. Through the agency of chemical action a considerable portion of this plant food may be made available that otherwise would lie inert.

4. A superabundance of water necessarily shortens the period of cultivation. Soils can not be cultivated profitably while they are wet. The period of cultivation, then, can not extend through the season of drying. This frequently seriously interferes with the period of growth of ordinary crops.

5. Each year much damage is done throughout the country by winter killing, or "heaving out," of wheat, clover, grass, etc. This can only take place when the soil contains a considerable amount of moisture. Dry soils do not heave. (See "Tile Drainage," page 22.)

6. Land that suffers from excessive moisture during a portion of the year usually suffers most through drouth. Drainage not only prevents the ill effects of excessive moisture, but also modifies the ill effects of drouth. (See "Tile Drainage," page 25.)

In studying drainage, water may be studied under four heads:

1. Water flowing over the surface,
2. Hydrostatic water,
3. Water held by capillarity,
4. Hygroscopic water.

1. Flowing water, if in small quantity, should be removed by drainage after passing slowly through the soil. Streams of water should not be allowed to flow continually over the soil except in permanent water courses.

2. Hydrostatic water, or stagnant water, is that which is held in the soil by impervious subsoil and naturally escapes by evaporation. This may be removed by drainage if a proper outlet be provided. The surface of the stagnant water is spoken of as the water table. When the soil has an impervious subsoil without artificial drainage, the water table may be at, or even above, the surface of the soil if the precipitation is greater than the evaporation. In time of drouth the water table is lowered, but that does not fit the land for the growth of crops. Loam or clay soils under these conditions become too compact for plant growth. (See "Tile Drainage," pages 10-11.)

3. Water held by capillarity is that held in a porous soil by virtue of the power of water to raise itself in small tubes. This action is very similar to rise of water in a sponge or blotting paper, or oil in a lampwick. The amount of water held in this manner is not detrimental to plant growth and would not be removed by drainage. (See "Tile Drainage," pages 9-10.)

It has been found by actual trial that ordinary arable soils have the power of absorbing by capillarity from 35 to 70 per cent. of their weight of water. It is also well known that thoroughly drained soils have much greater capacity for holding capillary water than those that are undrained. (See "Tile Drainage," page 25.)

The average of a large number of tests of drained and undrained soils shows that drained soils will hold about 12 per cent. more water by capillarity. Ordinary soils weigh from 3,000,000 to 4,500,000 pounds per acre for the first foot.

Bearing in mind that one inch of rainfall weighs about 113 tons per acre, some idea of the vast amount of water stored in the soil by capillarity for the use of the plant may be obtained.

The question of supplying water for growing crops is each year receiving more attention than ever before.

4. Hygroscopic water is water absorbed by fine dry soil from the atmosphere. The moist condition of the dust in the road or a fine fallow field in the morning is due to this moisture. Plants may use water so absorbed from the atmosphere.

TILE DRAINAGE.

Question Paper No. 1.

Students will discuss freely the following topics, not confining themselves to the lesson sheet but use information gained from other sources.

Send answers to the Superintendent as soon as completed, when other lesson sheets will be forwarded. In no case will the second lesson sheet be sent until the questions of the first lesson are answered.

1. Discuss the history and development of drainage.
2. Explain how the removal of surplus water tends to make the soil mellow.
3. What effect does the removal of the water have on the temperature of the soil? Discuss fully.
4. In what way does the removal of water by drainage furnish growing crops with water in time of drouth?
5. How may drainage increase the fertility?
6. In what way is an excess of moisture injurious to germination?
7. Compare hydrostatic water with that held by capillarity.
8. Of what use is hygroscopic water
9. Of flowing, hydrostatic, hygroscopic water or water of capillarity, which is of the greatest importance to field crops
10. How may drainage lessen the ill effects of winter killing of wheat, clover, grasses, etc.?"

During the past ten weeks two hundred and seventy-five lessons have been sent out to the students in the Chautauqua Course and the number applying for these lessons is continually increasing. At the present time nearly twenty-eight hundred students have been enrolled in this Course.

The increasing demand for these lessons, which necessitates a great deal of labor not only in their preparation but in correcting the examination papers, makes serious inroads on the time of those who have this work in charge. If further extension of the work is desired, or if it is even to be maintained in its present condition without sacrificing other work of the Department, an assistant should be provided who can give nearly all if not his whole time to the Chautauqua work.

The addition of these lessons to the Course has done more to bring it into popular favor than anything that has heretofore been attempted. From the trial thus given these lessons it is evident that they will form an important feature of the Chautauqua work in the future as they admirably meet the present needs of those who wish to take a somewhat extended course of systematic study at their own homes.

Most respectfully submitted,
G. C. WATSON,
Professor of Agriculture.

State College, Pa., December 15, 1897.

III.—BIOLOGY.

To the President:

Sir:—During the past year many improvements connected with the work in my charge have been made. Chief among these was the refitting of the laboratory. The room used for this purpose has heretofore been fitted with tables only, and these have taken up considerable room, while they failed to provide that firmness and resistance to jars which is essential to the best results. After a careful examination of more than twenty laboratories used for similar purposes, it was decided to place a wall table around two sides of the room, providing nearly fifty feet of length, and to place lockers on the walls above this table. These changes have been made and have proved to be decided advantages. Formerly the laboratory could accommodate only fourteen students at one time; now it will accommodate about twenty. Much floor space has also been gained by the change, and I know of no laboratory of its size which is now better adapted to the work for which it is intended.

In the way of equipment also, much progress has been made. A series of Ziegler's wax models of the development of the chick has been imported, besides another series showing the general principles of development. These models will be used with several classes each year, and will greatly aid both class room and laboratory work, besides attracting much attention in the museum.

The museum has now been open to the public for a little more than a year since the collection of birds and mammals was added, and during this period over 2,500 visitors have examined the objects on exhibition there.

During the year the collection of insects has been arranged in the new cases and considerably added to, several thousand species now being represented. It is my desire so to add to this collection that specimens of injurious insects in all their stages, and of the injuries they cause, may be shown there together. As far as I can learn, there is but one such collection in this State and that is not open to the general public, hence the greater need for such a collection here.

In this connection the work of the Senior class of the Course in Agriculture may be referred to. The importance of a careful training in the study of Insects in their relation to crops becomes manifest when we consider that the most careful estimates of losses, in this country, due to injurious insects, place the sum at over $380,-

000,000 annually. A large proportion of this loss could be avoided if a knowledge of Enconomic Entomology were general. With these facts in view, the Seniors of the Course in Agriculture are given eight hours a week during the Fall Session, in practical Entomology. In the class-room a general survey of the different groups of insects and a study of their relative importance to man is given, particular attention being directed to the most common injurious kinds. In the laboratory hours the class collects in the fields, gardens and orchards; pins, mounts and determines the species captured; investigates the literature of the subject, and selects the remedies most likely to be successful in each case. This method gives a familiarity with insects and their work which cannot but be of great utility. This course has been put into full operation this year for the first time.

As regards the remainder of the biological work there is little to report. The different classes have accomplished results which were satisfactory to me, and have shown themselves much interested in the subjects studied, and with the added facilities now available it is hoped that a still higher grade of work may hereafter be obtained. Over one hundred volumes of biological journals have been bound and can now be placed in the hands of the students for study of the original sources of much of the biological knowledge of the present day, which is always a strong incentive to better work.

The only recommendation I have to offer is that the museum cases now containing the specimens of invertebrates be replaced by others which are dust-proof as soon as it may be found feasible to do so.

Respectfully submitted,

H. T. FERNALD.

State College, Penna., December 18, 1897.

IV.—BOTANY AND HORTICULTURE.

To the President:

Sir:—In the Department of Botany and Horticulture the scheduled exercises, as laid down in our catalogue, have been followed with only minor changes.

The subjects considered, the hours devoted to each and the number of students in the respective classes are all so clearly stated there that it is unnecessary to repeat it here. There have been no changes in text-books nor in the general method of instruction. The strength of the work lies, in my judgment, in the practicum exercises, a fact not always appreciated by the outside public or the undergraduate student.

I beg leave to call your attention to the laboratory charge in Botany. In conversation with you I have several times referred to it, but have never made it a matter of formal report. By reference to laboratory expenses, page 173, it will be seen that the fee in Botany is one dollar per term; much less than that in any other subject, a number of which are not attended by any more expense. As a matter of fact the fee does not meet the expense as laboratory work is now conducted. I therefore request that the charge be made two dollars instead of one.

The larger size of the classes this year, together with the call for work in Horticulture, both in the regular and the special Agricultural courses, has shown the inconvenience and inadequacy of the Botanical building when all our courses of study are in operation. The large second floor room is the only one well fitted for either recitation or laboratory use, hence when two exercises are scheduled for the same hour it has been necessary to accommodate the smaller class in some other place. The other second floor room is needed for the herbarium and for private work, while the only available room in the first floor is partly used for museum purposes. While we can "get along" under present conditions it is obvious that should our numbers increase, as we may reasonably expect they will in the near future, we shall need additional room.

The requirements of the Chautauqua Course in Agriculture and correspondence upon botanical matters referred to me call for an increasing expenditure of time and energy, but believing them to be a legitimate part of our work I always endeavor to give them reasonable attention. The additions to equipment consist of two hundred specimens by purchase, a smaller number by collection, and some long-needed books and cases for the department library.

Very respectfully submitted,

W. H. BUCKHOUT.

State College, Penna., January 20, 1898.

V.—CHEMISTRY.

To the President:

Sir:—The work of the Department of Chemistry during the year just closing has been marked by no unusual circumstance or result which calls for special report, but, in a general way, I may state that I am pleased with the work accomplished within the last twelve months. It is true that more advanced chemical research of some merit has been accomplished in our laboratory than ever before, and it is further true that the elementary work has been carried through with fewer "conditions" than usual.

Graduate Students.—Again it is my privilege to report that another graduate from our department has been promoted to the doctorate by the philosophical faculty of the University of Göttingen, on the strength of efficient resident work, a satisfactory thesis and a well sustained examination. He found employment immediately on his return to this country and is now superintendent of an oil refinery in Toledo, O.

Our own Master's degree was also conferred upon one alumnus at the last commencement in recognition of work accompliushed in chemistry and three others are enrolled as applicants for the same at the present time.

Occupation of Graduates.—I note with much satisfaction that the graduates from this department are more and more finding employment with manufacturing concerns, and being placed in charge of departments of the manufacturing plants rather than employed as mere analysts. This is as it should be, for through this kind of chemical work, rather than through the analytical laboratory, lies the path towards the most substantial success. It is exceedingly important that the student should early become proficient in analysis, and the respective branches of Qualitative and Quantitative Analysis must be kept prominent and strong in the college curriculum, for without them the student can do nothing. But after gaining familiarity with analysis, the student should see a much wider horizon opening before him. In other words, analysis should be the means to an end and not the end itself. It is my hope that, while Analysis, Qualitative and Quantitative, must be taught no less vigorously than in the past, our facilities for instruction in Industrial Chemistry, now far too meagre, may be increased and greatly developed in the next few years. In this connection I note the recent public announcement of the establishment of departments of Industrial Chemistry in two of the most widely known technical institutions of this country. This is little other than what we have been doing here for some years, though probably those institutions just referred to have been able to become more efficiently equipped along this line than we have and are therefore justified in making more attractive public announcement. Again, at the date of this report, as on certain occasions before, I am able to state that there is a call for a larger number of competent, thoroughly trained, efficient chemists, than we are able to supply.

Changes.—A few slight changes in the curriculum have resulted in markedly improving it. A systematic study of Current Periodical Literature now extends throughout the last year of the course, one hour per week. A course of lectures on the Compounds of Carbon, two hours per week during the fall term, is now given to all non-engineering sophomores. It is believed that this introduction to a branch of Chemistry of rapidly growing importance, will serve as a helpful preliminary view of the field for our students of Biology and Chemistry; a help in understanding Plant and Animal Chemistry for our students of Agriculture; and a necessary and desirable outline of the organic field for General and Latin Science students who, though they finish Chemistry at this point, are to go out from us as men trained, at least in the elements, of all science.

Inspection Trips.—Though not a part of the curriculum as it appears in the catalogue, yet an exceedingly important feature in our instruction, is the trip of inspection taken in the spring vacation with seniors and juniors. I do not overestimate the value of this feature when I say that it is of more consequence as an element in the development of our students than the longest and the fullest, the best and the most complete term of chemical instruction which they ever get in college. Since we do not make use of the two weeks summer school, authorized by the Trustees and required of students in some other courses, I hope that we may soon see our way to requiring this spring trip, which is of far greater consequence and value than the summer school could possibly be made, unless perhaps by using our summer time in this same manner. My expectation is to visit such points of chemical manufacturing interest in the western portion of the State in one year as may be practicable, and in the alternate years to visit similar plants in the East. If the senior and junior chemists go each year, every student would get the advantage of both trips during his course.

Last year we went westward, the limits of distance being Pittsburgh and Franklin, Pa., and Buffalo and Niagara Falls, N. Y. The trip covered nine days and we inspected some twenty manufacturing establishments, including the following industries:

Articial dye-stuffs,
Beer,

Bessemer steel,
Bye-product coke,
Calcium carbide and acetylene,
Carborundum,
China,
Gas—Water gas and other fuel gas,
  Coal gas and other illuminating gas,
Glass—Plate glass,
  Pressed Glass,
  Window glass,
Lead refining,
Linseed oil,
Litharge and red lead,
Oil refining,
Soap, candles and glycerine,
Sulphuric acid, manufacture,
Sulphuric acid, recovery,
Tin plate,
White lead.

It was a hard trip but the students entered into it with enthusiasm and carried it through with unflagging interest. The broadening influence of such a work as this cannot be overestimated, and I repeat that I hope to make it a requirement, at no distant date, of the junior and senior years. The chief objection is the expense, and since our chemical students are already burdened with expenses which other students do not have to meet, I am not sure that it is best, for the present at least, to make the inspection trip an annual requirement in the regular curriculum.

Museum.—I am pleased to report that this feature of our equipment is sustaining a reasonably rapid growth. It has been impossible, for lack of help and resources, to advance it as rapidly as we could wish during the last year, but something is being done all the time and we trust that the halt in the development of the museum is temporary only.

Assaying.—The assaying laboratory is at present better equipped than ever before and the character of the work accomplished by the students is on the whole satisfactory. The greatest need now, as I have indicated before, is an increase in the time allowed to the study of this branch. Students are scheduled for four hours per week for the fall term. This means about forty-five hours altogether. This time should be increased to at least ninety or a hundred hours, and we would prefer junior time rather than senior. So many students now come regularly to the assaying laboratory, that this room should have a separate entrance. This could easily be secured by converting into a door the window next to the main entrance.

Instruction Force.—The personnel of the department remains the same as at the date of my last report. The necessity is even greater than at that time for the employment of at least one more man. Especially after the fall term in each year we feel very severely the pressure caused by our working short-handed, yet we finished last year without catastrophe and may do so again. At all events our purpose is to overwork ourselves another year rather than ask that this assistance, which we formerly had, be restored.

Laboratory Space.—In previous reports I have emphasized the fact that the quantitative laboratory is insufficient in size to accommodate the students who are scheduled to report there for work. While a relief laboratory can not be furnished this year, I still hope that the time is not far distant when the much needed relief will be afforded in some way. Still more urgent is this need as seen from the requirement of another portion of my work. In my last report I spoke of the instruction in Gas Analysis as carried on at that time in the lecture room, though most inconveniently to all parties concerned. The last class to come in for instruction in that branch was so large that we had to desert the lecture room and had no place to go except into the unfinished open space in the attic. Here a table, forty feet in length was constructed and used during the last spring term. I need not tell you that an attic space, open to the outer air with no means of closing all the windows, unprovided with any means of heating, is a dangerous place for class work during the treacherous weather of this climate in the early weeks of our spring session, but here it had to be done in 1897, and here it will have to be done, if accomplished at all, in 1898. This is not right but it can not be helped with our limitations so ordered as they are now.

Library.—The chemical library is a much used and very essential portion of our equipment, but one which suffers much from neglect. It is some years since any very important additions have been made to it and it is rapidly falling behind the relative position which it held a few years ago. Many additions should be made and new subscriptions to periodicals entered. In this connection, it might not be improper to state that, with reference to the wants of my department, I deplore the disappearance from the general library and reading room, of the Journal of the Franklin Institute, a journal so helpful to the chemist that our students should surely have access to it, yet so important for other scientific and engineering students that I never felt it right to ask to have it transferred to the department library in the laboratory building. I sincerely hope it may be restored to the general reading room.

Building and Repairs.—Since the rather extensive repairs to the building two years or more ago, there has been no further trouble from inadequate heating and ventilation of the rooms. The minor matter, however, of the special ventilation of fume chambers or hoods, has never been right and will sometime call for renewal. When the building was first equipped, an inadequate fan was placed in position, through no fault of the writer, and called upon to do this work. It has had a remarkably long life already and is still doing its work, but is flagging perceptibly, and whenever the time comes for its renewal, whether this year or next, I hope it may be replaced by a fan more suitably adapted to the purpose and actuated preferably by an electric motor attached to the general plant. Other repairs, aside from a needed entrance to the assaying laboratory as above mentioned, are slight and consist chiefly of the renewal of lead pipe and trough linings from time to time which must now be expected to be consumed at a tolerably steady rate annually.

Summer School.—The laboratories were kept open during the last summer for the convenience of such students as might claim the privilege of the summer school advertised by the College. The number of students was very small but our duty towards the summer school organization was sustained to the letter and a beginning has been made. We hope for more students another summer.

Semi-Annual Examinations.—This department will welcome the change as soon as it can be brought about, from our present system of examinations, to one which shall call for only two instead of three examination periods annually. The present system of consuming three weeks for examinations, where two would do, causes an unnecessary loss of one week out of the year, a loss which is common to all departments of course, but one which we are sorry to suffer. Further, the varying practice of different departments in this important matter makes it difficult to conform properly to the present requirements.

Student Expenses.—It has long been my hope that some dispensation might eventually be reached here which would lighten the burden of personal expense to students of Chemistry. Possibly I could not bring this matter up in better form than by quoting the major part of a communication dated October 16, 1896, which though semi-official, was not a part of any published report. The communication grew out of your suggestion made on an earlier occasion, and ran as follows:

"To the President:

Dear Sir: In one important respect I have long felt that my department has to do its work at a disadvantage; I refer to the charges made to students for materials used in instruction.

These charges are kept as low as we can keep them consistently with good work, and I have always maintained a measure of satisfaction in the fact that our students have been supplied with the best equipment at less expense than the same facilities are costing other students at many colleges. Nevertheless this expense is very considerable and bears heavily upon many of our students. For each individual under our present arrangement of studies, the required Chemistry costs about $30. For those who elect the course in Chemistry, the expense is not under $100 for the four years.

Though this is quite customary here and elsewhere, I can not think that it is right. The custom grew up in classical colleges and universities where laboratory methods of instruction were looked upon with suspicion, and it was necessary for those who insisted upon indulging in such things to meet the expense out of their own pockets. This custom has been very naturally transferred to the industrial and technical institutions as regards their chemical departments but has rarely been applied to any extent in other departments.

It is self-evident that the inauguration of technical departments entails upon a college heavy expenses for material things which must be met in some manner. But why should chemical students be charged with their material expenses, while similar material expenses are quite free to students of Agriculture or Architecture, of Engineering or Mining, in most of our colleges, or are included, nominally, in the charge for tuition?

The line between permanent and perishable apparatus is not a sharp one. It is rather an imperceptible one and an impossible one to draw. A test-tube costs five cents, is used perhaps by one student an is destroyed; a telescope costs $5,000, is used perhaps for a hundred thousand observations during many years before it is retired as useless, but the student who uses the test-tube, and he who employes the telescope, both enjoy their five cents' worth of material aids to instruction; the chemist finds it charged on account, while the astronomer's use of the instrument is met by the College.

And so on:—

A Beaker costs 10 cents, lasts 1 day, is used 1 time; $\frac{10c}{1} =$ 10c.
A Crucible costs $10, lasts 1 year, is used 100 times, $\frac{\$10}{100} =$ 10c.
A Microscope costs $100, lasts 10 years, is used 1,000 times, $\frac{\$100}{1,000} =$ 10c.
A Dynamo costs $1,000, lasts 20 years, is used 10,000 times, $\frac{\$1,000}{10,000} =$ 10c.
An Experimental Locomotive costs $10,000, lasts 50 years, is used 100,000 times, $\frac{\$10.000}{100,000} =$ 10c.

Each student receives the worth of a dime from his employment of any of the above articles of equipment. Part are charged for while part are not. I believe there is a manifest lack of fairness here.

But the case is not so evenly balanced as this crude illustration would make it appear. I believe it costs any college more to equip and maintain a department of Mechanical or Electrical or Mining Engineering than to equip and maintain a department of Chemistry. I think it costs this College a much larger amount to educate each engineer and each agriculturist than it costs to educate each chemist. If this be undeniable, as I believe it is, why should a chemical student in The Pennsylvania State College be charged $100 for his material while it costs the engineer and the agriculturist practically nothing?

Manifestly the reason is to be found in the tangibility of our chemical apparatus. We handle many thousands of single pieces of a few cents' value each and this cost can be assessed as articles are issued to students, while in other departments it would be more difficult to make the fair charge. And there is no other reason! My claim is that this is an unjust discrimination against the student of Chemistry, in spite of the prevailing custom of colleges.

In making this plea for the removal of charges against students for material consumed in chemical laboratories, I am aware that I am proposing an innovation, but it is an innovation which might most appropriately be made at a State College, and I recommend it as a most desirable thing in this State College.

One of the greatest difficulties in the way of such a plan arises from the very probable danger to abuse of the system. If chemicals and apparatus are made free to students, the tendency to carelessness will be great and it will grow. But this can be carefully guarded against. If this step should be taken in The Pennsylvania State College during my connection here as professor in charge of the Department of Chemistry, I should urge the necessity of most stringent regulations to guard against the abuse of the privilege, and would have no hesitation in placing myself in a position of responsibility for this very thing. The first laboratory deposit should be required of all students as heretofore. Individual accounts should be kept with each student exactly as in the past. Every one might be allowed as a credit for breakage, such an amount as is shown by our experience in the past to be necessary and reasonable, but all excess should be charged for and collected. Detailed regulations would be adjusted as necessity might arise, and I am positive of the entire feasibility of the plan."

This will suffice to show you, sir, that the present conditions still seem to me undesirable. I am still unable to find a sufficient reason why students in the engineering laboratories may draw steam from the steam pipes, and tap the wire for the electric current, all they want of it, free of charge, to perform their necessary experiments, while the student in the chemical laboratories must needs find a charge entered up against him for every use of gas from the gas pipes, no matter how legitimate and necessary the purpose for which it was used.

In closing, I may perhaps be believed when I say that this department has many needs and many more wants, but proposes to make no requests and press no claims at this time.

Very respectfully,
G. G. POND,
Professor of Chemistry.

State College, Penna., December 27, 1897.

VI.—CIVIL ENGINEERING.

To the President:

Sir:—The work of the Department of Civil Engineering was described at some length in my report for the year 1894. During the past year practically the same lines have been followed as were there laid down. I will, at the present time, speak briefly of a few points connected with the work of the department.

The Engineering Summer School has proved, after a trial of four years, that its establishment was a wise move. The beneficial results of the three periods of two weeks each, devoted almost entirely to field work, are apparent in the facility which students acquire in the use of instruments. While this is far from being the most important part of their training, it is very valuable to them in entering upon work after graduation, as it gives confidence both to themselves and their employers.. A brief description of the work of the students in this department during the last Summer School may be of interest to you.

The Freshman Class, in addition to learning the use of the common instruments, made a survey of a portion of the campus and the borough. During the fall session just ended, each student has made, from his own notes, a map of the survey on which he was engaged. This work, before the establishment of the Summer School, was not taken up until the Junior year.

The Sophomore Class made a complete plane-table survey of a large section of the campus. In this way we are gradually making a valuable topographical map of the campus, while the students are, at the same time, having the necessary training in practical work.

On account of the absence of any large stream of water in this vicinity it has been found necessary to take the Junior Class to some other locality for their work in Hydraulic Measurements and Hydrographic Surveying. This work is in charge of Assistant Professor Beyer, who, last summer took the class to Jersey Shore on the West Branch of the Susquehanna river. Here soundings and gaugings of the river were made, together with a survey of its banks.

During the next Summer School we hope to be able to take the class to a place where there is a body of still water, as we wish to rate our current meters and do some other work which can best be done on still water. A lake, situated near a river is the ideal place for this work. As we shall be obliged to go some distance in order to obtain the desired conditions, an obstacle presents itself in the cost of the railroad fare. Heretofore we have been able to keep the expense of the trip at quite a low figure, as places have been found within a short distance of the College. I trust that it may be found possible to make some arrangement with the railroads whereby the cost of transportation may be kept at a reasonably low figure.

I had hoped that, with the appropriation made for this department, a considerable amount might be expended to form a nucleus of a Hydraulic Laboratory, but I fully appreciate the circumstances which made it necessary to apply a large part of the appropriation for a purpose of equal importance in the maintenance of the department. Still, it has been found possible to set aside, from this year's portion of the appropriation, a small amount for the purpose indicated and I trust that a still larger sum may be added during the coming year.

There have recently been added to the library of this department complete sets of the Engineering News and the Transactions of the American Society of Civil Engineers, as well as several other books. It is our desire to procure complete sets of several other engineering periodicals and to add, from time to time, such new books as may be of value to the student of civil engineering.

The resignation of Mr. Siebert, which took place during the summer, was a serious loss to the department. The work of instruction has, however, been so re-arranged that, with the addition to the teaching force as Assistant of Mr. C. W. Lawrence, of the last graduating class, the work has been carried on with satisfactory results.

Respectfully submitted,

F. E. FOSS.

State College, Penna., December 21, 1897.

VII.—ELECTRICAL ENGINEERING.

To the President:

Sir—With the closing of the calendar year 1897, I am glad to have the opportunity of chronicling a continued advance in the work of Electrical Engineering. Any thorough and efficient college, such as is The Pennsylvania State College, is certain each year to show an improvement throughout all the general lines of work. Moreover, the branches of such an Institution are so interlinked that each Department is directly affected by the work of the others, so that if there is a weakness at any point it is apt to be felt throughout the entire course. I can say with entire confidence that the preliminary preparation of the Junior and Senior classes that have come to me this fall has been materially better in every respect than heretofore. This is especially noticeable in the cases of Elementary and Applied Mechanics as well as in Mathematics and Steam Engineering.

Although the above statements are not more than you have probably a right to expect, they are a clear indication of a hearty growth of the Institution in the right direction.

Electrical Courses.

The work in Electrical Engineering is improving, partly on account of the steady enlargement of the laboratory equipment, which is enabling us each year to offer more complete and satisfactory facilities. I wish to add, however, that I consider it imperative that our equipment be very largely extended in several directions, such as the establishment of an electro-metallurgical laboratory, if we are to keep abreast with the best technical colleges of the country. I can name a number of these Institutions with which we rank, where much more money is expended annually upon the electrical laboratories, and in which the Department of Electrical Engineering is at least twice as old. The class-room and draughting-room work has improved from the fact that the students come to us better prepared, and are therefore able to cover more ground, and, at the same time, do it more thoroughly. Also, the rearrangement of the Courses made between two and three years ago has enabled us to get this work more and more fully correlated until now we have essentially a continuous course in electricity extending from the Spring Term, Sophomore year, to the end of the course, in which theory and practice are carefully combined.

The establishment of a School of Engineering has also borne much fruit as an aid in the growth of all the Engineering Departments.

The fact of having a general organization has made possible much improvement in the uniformity of the work and has prevented anything approaching duplication or discontinuity in the courses. This was clearly evidenced during the past session when the absence of the head of the School was keenly felt, the School management being performed by one unfamiliar with many of the duties.

There is an important matter in which a majority of the colleges giving strong courses in Electrical Engineering are gaining an advantage over us, which is the increased amount of time they are enabled to give to higher collegiate work, due to their more advanced entrance requirements. This is partially balanced by our two weeks' Summer School, but not entirely. A large majority of these institutions require at least all of Geometry and one year of Modern Language. Many require much more. Such a change at this Institution would raise our standard of graduation as much as did the establishment of the Summer School. From a careful study of the courses of about two hundred high schools, I am convinced that these schools could readily meet a reasonable advance in the requirements of this College.

Instruction Force.

During the summer, Mr. H. A. Lardner resigned his position as Instructor in Electrical Engineering, much to my regret, as his work was entirely acceptable, but the Executive Committee have replaced him by a man whose previous training is excellent, Mr. Budd Frankenfield. Mr. Frankenfield spent three years at Leland Stanford Junior University, during which time he received instruction in Machine Design under Professor A. W. Smith, an accepted authority on the subject. He then graduated at The University of Wisconsin, in Electrical Engineering, with the degree, Bachelor of Science. He followed this with a post-graduate course, for which he received the degree of Electrical Engineer, afterward teaching in the Department of Electricity at the latter Institution. He has also had some practical outside experience.

The time which has elapsed since he joined us has been so short that he has not as yet been able to show his capability, though the teaching work assigned him during the Fall Term has been well done.

The remainder of the staff has not been changed.

Electric Lighting.

In accord with your instructions to Professor Willard, his dwelling house has been connected with the College lighting circuits. His house is wired for sixty lights. The insurance company accepted the wiring of this house as it was done under my supervision, so that it has not as yet been regularly inspected by the underwriters' engineer.

The Armory has also been rewired, the centre row of clusters being replaced by four long burning arc lamps, which greatly improve the illumination of the building and, at the same time, reduce the power required.

The campus arc light circuits have been made independent and new lamps substituted for the old ones. This entails a yearly saving in labor of $75.00, in carbons of $76.50 and in coal of about $160.00. The saving in coal will be made by the fact that the arcs can be thrown on from one to two hours later than the other circuits and need not be burned on bright moonlight nights. I did not count the saving due to increased efficiency in this item, and assumed the cost of power at about one-half commercial rates. The service has also been much improved by the elimination of the flickering caused by the arc lamps on the house circuits and by the much steadier and stronger light given by the new form of lamp.

The lighting of the College Reading Room and Library has also been rearranged under your direction with a much improved service.

With these improvements out of the way the running expenses of the plant can be carried by the fees paid for lighting service. However, there are one or two important matters still to be attended to, one of which is the rewiring of the President's dwelling, which I have already brought to your attention, and the other is the necessity for rewiring the pole line from the Botanical Building to the grove. The poles supporting this line have rotted so that the wires can not be put into first class shape and will not stand at all much more than a year longer.

Thanking you again for your aid and that of the Executive Committee, which have been given me in the task of developing the Department of Electrical Engineering, I am

Very respectfully,
JOHN PRICE JACKSON.

State College, Penna., December 31, 1897.

VIII.—ENGLISH AND RHETORIC.

To the President:

Sir:—The English Department can report no changes either in work or methods during the current year. Thoroughness and practical results have been as usual rigorously insisted upon, and on the whole we have reason to be encouraged by the results of the year's work. We would, therefore, confine our report not to the work already established, but to a few of the needs and problems of the Department, some of which have been already brought before you.

First, we find ourselves constantly handicapped in our work by the fact that the books of the College Library are not allowed to circulate among the students. To study literature to advantage the student must read widely in the masterpieces and this can be done to advantage only when he has the books constantly by him in his own room. A surprisingly large percentage of our students never enter the library under existing conditions. Only about ten per cent. of the student body can now use the library at one time.

Second, it seems to the department that all courses should have English or American literature at least for one session. At present all but three or four students in every class finish their English studies at the end of their Freshman year, which year is given up, not to literature at all, but to the fundamentals of composition and rhetoric. A subject of such vital importance to every educated man, be he engineer or not, should certainly not be absent from the curriculum. This study could be offered in the winter or the spring session without adding to the present teaching force.

Third, there are no courses at present where students can specialize in English. There are at least two or three students in every class who are taking their college course here as a preparation for the law or for advanced standing in some classical college. Such students need as good a foundation as possible in literature and the humanities, and yet at present they can get but little more of English than do the Engineers. Either a new course should be established or the General Science Course reorganized to meet the needs of such students.

These are perhaps the most crying needs of the department at present. To enumerate others might lead only to confusion. In conclusion, then, I would repeat that along the lines already established the work of the year has been more than usually encouraging.

The cry of the Department is for addition rather than for change. Thanking you, Mr. President, for your constant interest and sympathy, I remain

Yours sincerely,
FRED. LEWIS PATTEE.

State College, Pa., December 24, 1897.

IX.—HISTORY AND LATIN.

HISTORY.

To the President:

Sir:—Having been appointed by the Trustees to give instruction in History provisionally, I herewith submit a brief report of the work in that subject for the Fall Session just closed. The subject comes at such a time that we cannot, in one and the same report, give a statement of the whole course consecutively, nor of the entire work of one class.

More than sixty students were enrolled in the Sophomore Class in History during the Fall Session, and nearly all that number entered the final examination. Of those who were examined, the larger part did very creditably, though quite a percentage did not pass. Many of these had done conscientious work and will, without doubt, make good their deficiencies on second trial.

We have used the text-book adopted several years since by the head of this department, long since thoroughly convinced that "it is the best universal history in our language." We have called careful and constant attention to the author's treatment of the subject, have adhered to his method, have not presumed to improve upon, nay, hardly to vary from it, except in so far forth as we have oftimes dwelt more fully upon what he had emphasized, or as we have, here and there, in consequence of lack of time, omitted such chapters or sections as seemed to us not really in the general current of history and as seemed not to effect its general trend.

We have conscientiously sought to supplement the author by helping the student to understand and clearly to follow him, by calling attention to particular features in the treatment of the subject, always laying large emphasis on the great factors—racial, social, etc.—which are constantly in play upon the field of history, and by contrast of periods, movements and characters keeping the student in hearty touch with the author and the subject.

We have also deemed it consistent with the course and with the period of advance thus far reached by the men under our instruction, to hold them to a daily account, by making the exercise a recitation in the strictest sense of the word. In other words, we have not assumed to fly in the face of so excellent a text-book by adopting a lecture system, nor have we presumed, even by a single additional lecture, to add to the arduous work now put upon our students in their attempt to master the requirements of even the shortest text-book on ancient, mediaeval and modern history.

The results of such a method are in our hands and may be seen if so desired. They show, for the most part, an intelligent grasp of the subject and an eager desire to become still more proficient in this most instructive and engrossing of all studies.

Having been called upon by the Trustees, suddenly and unexpectedly, to give instruction in a department of work which had been familiar to us for nearly twenty years, but from which we had been fully divorced of late years and since our connection with this College, we have found indeed a heavy burden. But the work has been stimulating. The students have been respectful, attentive, studious, eager to grasp the great features of the universal history of our race. We desire thus publicly to make record of their honorable work and of the pleasure which we have found in their instruction.

LATIN.

The work of this department for the year 1897, has closed without interruption and with profit both to students and instructors. Our numbers have not been large, but they are not decreasing and there are some very hopeful features in our work.

Two years ago, we raised our standard for entrance in Latin, making it, with some slight exceptions, equal to the standard of the best Eastern colleges. In doing this we have been obliged to omit some subjects and to substitute others suited to a broader preparation and to more advanced students.

It is a pleasant fact to record, that students who entered this department last fall came with a preparation fully up to the required standard, having read what was specified, or its fair and full equivalent. This fact is worth noting, for when our standard was much lower our students seldom measured up to it.

This broader requirement has several good effects. Students evidently will not dare to enter with a meagre preparation. The department can more readily reject such as are deficient. More difficult reading can be entered upon and progress can be made with two-fold rapidity. Larger and better subjects can be associated in our courses and so, perhaps, win more persons to them.

Following, very nearly, this new course the Sophomore Class has read selections from the "History" of Tacitus. Careful study was made of the idioms of the author, and the history was carefully compared with the style of Caesar and Livy. The history of the period was dwelt upon and particularly the weakening of the imperial and gradual strengthening of the military power.

In the Spring Session this class read the "De Senectute" and received some hints as to the nature of Cicero's philosophical teachings and the relation which they bear to the different schools of Greek philosophy. During the Fall Session, the class has read selections from the "Odes, Epodes and Satires of Horace." They have been held accountable for grammatical work, for a careful understanding of the circumstances under which each selection was written and for historical, geographical, mythological and other references. They have been taught to paraphrase and state in prose from the conceptions of the poet and have had careful instruction in the metres and scanning, as also in the life and writings of Horace.

The Freshman Class read Livy in the Winter Session and followed it with Virgil in the Spring. The incoming class, following the revised schedule, has read Livy, rather than Sallust. Selections from Books XXI and XXII have been read in class with daily grammatical study, particularly of tense structure and uses of the subjunctive. Great interest has been manifested in the work. Owing to better preparation more ground has been covered than previously; greater aptitude for translation has been evinced and daily tests in grammar have shown a good preparatory training.

Owing to readjustments in the work of the College, it was necessary to have some assistance in this department. This has been faithfully and efficiently rendered by Mr. I. L. Foster, a statement of whose work is partially embodied in this report.

Very respectfully,

BENJAMIN GILL.

State College, Pa., December 24, 1897.

X.—INDUSTRIAL ART.

To the President:

Sir:—There is little that is new to be said concerning the work of the Department of Industrial Art and Design. The work, though elementary, covers more than is usual, considering the amount of time allotted to it, and there is only needed larger opportunities to carry it beyond the present elementary stage.

I wish to express my appreciation of your effort to provide a larger class-room. The hall formerly occupied by the Washington Literary Society has been somewhat renovated and fitted with new desks for the use of the several sections of the Freshman Class in free-hand drawing. It has proven a decided advantage over last year's arrangement. Its location, however, is not all that might be desired. Being on the fifth floor, where the windows are low, as well as deep, and the ceiling is high, on dark days, and there have been many such, the light is insufficient even when the electric light is on. That, however, may be remedied by the introduction of a greater number of lamps.

Students' drawings have been put in frames used at the Columbian Exposition and placed on the walls, together with some colored foreign views of my own which have temporarily been hung in this room.

The case filled with casts of students' work in modeling, also from the World's Fair, occupies a conspicuous position and is surmounted by the bust of Senator Morrill.

An old octagonal table has been renovated, which serves well for the placing of many models. Altogether, the room presents a creditable appearance and will be very attractive when the new models are put in place.

The new models, upward of seventy in number, have been selected with the greatest care and with the purpose of presenting as wide a range of subjects as possible. Since the amount to be expended was not large, it was necessary to make some sacrifice in size in order to secure variety.

The new desks, though simple in construction, have proven very satisfactory for our work and leave nothing to be desired, unless it is an adjustable shelf on which to place small models.

I thought it might be possible to do without a blackboard, but my experience this session has proven that it is a necessity, and I therefore hope that this room may be provided with an adjustable slate blackboard.

The total number of students receiving instruction in this department this session is one hundred and thirteen, a majority of whom have shown a satisfactory interest in their work.

Respectfully submitted,
ANNA E. REDIFER.

State College, Pa., December 20, 1897.

XI.—LIBRARY.

To the President:

Sir:—It gives me great satisfaction to report an improved condition of the Library as compared with that existing last year.

While still occupying its inadequate quarters in the main College building, it does not at present suffer from an accumulation of unshelved books. Two new steel stacks 9¼ feet long by 8¼ feet high, the first, it is hoped, of a series planned to fill the centre of the book room, were put in positoin during the summer vacation. The books were arranged, single rows substituted for double ones on the shelves, and the new stack largely occupied at once. The work was superintended by the Assitant Librarian, Miss Anna MacDonald. Unfortunately, the relief was temporary. So rapidly have some of the cases filled that a resort to double rows may soon again be necessary.

During the year 1897, 1,447 volumes were added to the Library. Of these, the Department of Civil Engineering added 99; Biology 99; Mining Engineering 45; Botany 42; Chemistry 35; Electrical Engineering 31; History 18; Psychology 16; Agriculture 3; Mechanical Engineering 1; Art. 1. Two hundred and ninety-five are Government and State publications, and 586 are old books received from the Washington and Cresson Literary Societies. Some of the latter are valuable accessions, but many of them are practically useless to the Library. Its actual gain is much less than the figures given would imply.

There are many old books of which no disposal has yet been made. These are duplicate sets of the British Classics, which are for the most part in good condition, a few books valuable in their subject matter, but so well worn as to be unfit for further service, a number of text-books no longer in use, and lastly, a condemned pile of the utterly worthless. All of these should be disposed of by sale, exchange, gift or bonfire, in order that the room they occupy may be available for other purposes.

No new books have been bought for any of the departments of literature. The omission is a serious one, as the collection now on the shelves fails entirely to meet the demands of the literary departments of the College, or to furnish in at all a satisfactory degree, the supplementary reading essential to the carrying out of any comprehensive scheme of instruction in those departments.

Especially is this true of the department of English Literature in the line of fiction. The modern library, as a rule, has a tendency to exaggerate the importance of fiction and to give it an undue prominence on its shelves. While the tendency is to be deplored, and it must be admitted that the absence of all fiction is undoubtedly the lesser evil, it is still true that the library should contain the best works of all standard authors. It is much to be regretted that the resources of the Library are not sufficient to enable it to supply itself with at least the more important books of the day which are absorbing the attention of the reading public. The purchasing is almost exclusively confied to those books of which there is pressing need in some department of college instruction. Acknowledging that these needs should be promptly met, it is evident, in viewing the Library as a whole, that this method leaves much to be desired. There are many books whose value does not depend upon their touching the special work of any department, whose claims to attention are yet indisputable.

The addition of the new stack has been attended with one disadvantage in that it has lessened the capacity of the room in which it has been placed, as a reading room. Both the reading room proper and the book room are often uncomfortably crowded.

The reading room has many other deficiencies. Only two daily newspapers are received, and while the magazine list has improved, some of the periodicals most often called for are not included. The preservation of the magazines and the comfort of the readers would be subserved by the purchase of a magazine case, which would relieve the tables and make it possible to find the periodicals desired without difficulty.

The daily attendance in the reading room during the year averaged 84.

It has been a gratification to note that the reading is less confined to the periodical literature, and that more books are taken from the shelves than formerly.

The experiment is being tried of opening the Library on Sunday afternoons. It has been very successful, the attendance during the two hours from 3 to 5 ranging from 16 to 32. The rooms have also been opened recently on Saturday afternoon from 2 to 5. The result has been only a small attendance so far, owing possibly to the the examinations at the close of the term.

Some books have been added to the reference library, viz: The last volume of Poole's Index, the American Catalogue for 1890-95, and the Century Dictionary of Names, completing the Century Dictionary already owned. Other sets should be completed, notably the English Dictionary of National Biography, of which the Library has only nine volumes.

LIBRARY OF THE UNIVERSITY Digitized by Google

One of the most important questions is still the binding of the magazines. The small appropriation set aside for the purpose by the Legislature of 1896 is entirely inadequate. The binding has been so long neglected that much more than the amount allotted will be necessary to cover the expense.

In the end, it is sufficient to say that all needs are merged in the great one of a new library building, properly equipped and adapted to the ever growing demands of an ever growing college.

Respectfully submitted,

HELEN M. BRADLEY.

State College, Pa., December 31, 1897.

XII.—MATHEMATICS.

To the President:

Sir:—I have the honor to present the following report for the Department of Mathematics:

During the year eighteen ninety-seven the largest number of hours yet taught has been scheduled for our department.

The results of examinations which I have taken pains to tabulate and analyze in all subjects, and some very generous words from members of other, and especially technical, departments lead me to report a year of progress.

This is in spite of the fact that we have employed one less than our maximum number of instructors. I believe this measure of success is due to the fidelity and ability of my associates which has never been more apparent than during the year about to close.

I wish to call attention to a single fact also, which seems to me to have a bearing on the advancing needs of my department. Four members of the present Freshman Class passed examination in Solid Geometry this fall upon entrance, and substituted other work in hours thus set free. Three other men proposed to try the same examination but finally did not do so, partly esteeming their preparation insufficient and partly desiring to give greater care in laying the mathematical foundations of their scientific work.

While I should be slow to infer any general improvement in mathematical preparation, I think I see here the first fruits of a suggestion made in the previous report. I took occasion there to make a somewhat detailed statement of two critical points in our work, with the remedies suggested and adopted when the present scheme of courses was arranged. These points were:

1. That all Engineering students, as well as those taking the courses in Mathematics and Physics, require knowledge of the Calculus and its applications by the end of the Sophomore year. All students are rushed the first two years in mathematics to meet this necessity. This, while it leads to a point of congestion and failure at the end of the Sophomore year, also makes it absolutely impossible to avoid.

2. Putting all we do of Solid Geometry and College Algebra into the Fall Session of Freshman year.

When the courses were arranged it was planned to require Solid Geometry for admission at the earliest possible time and thus relieve a few hours in favor of the College Algebra (a thorough knowledge of which is of the utmost importance for the work that follows) and for making up of other common deficiencies in the Metric System and in actual ability to compare and compute results.

In the report above referred to, I asked that some statement be made to the public that the College will require all Euclidean Geometry, and, if thought advisable, fix a definite date.

I believe all those who have taken the examination for advanced standing this year are in the engineering courses. If this requirement for admission could be made for such courses alone, the Scylla of the Freshman year and the Charybdis of the Sophomore year would become a part of our Mythology.

It is my duty also to mention that we need another man during the Fall Session at least, as soon as the finances of the College will permit, in order to do the most efficient work.

We sadly need additions to our mathematical library. . The books we have are used more this year than ever before. Some time since a small amount was appropriated for the mathematical library and has amply justified itself. At that time I made out a considerable list with estimates. I would be glad to have these ordered. If this cannot be done at present a small appropriation should be made to purchase the few books absolutely required, mimeograph stationery, etc.

I would be glad if some room could be assigned us with tables for making models and computing results; it should contain a case for books of reference and a dozen chairs and stools. It would be a great advantage to us if such a room could be fitted up for us on the first floor of the main building.

The expense would be slight (less than $150), would give opportunity for personal supervision of certain student work, and form a much needed headquarters for the Mathematical Department. If No. 105. now used as a store room, could be assigned to the classes in mathematics, now somewhat crowed in No. 106, the latter room would be admirable for the purpose.

It gives me pleasure to call attention to the fact that two students graduated from the College this year, enrolled as students of Pure Mathematics. Their zeal and scholarship, as well as their Thesis work, leads me to believe that they will be a credit to this institution.

In closing, permit me to make renewed expression of thanks to you for the consideration you have given the Mathematical Department as well as myself.

Very respectfully submitted,

J. M. WILLARD.

State College, Pa., December 27, 1897.

XIII.—MECHANICAL ENGINEERING.

To the President:

Sir:—In view of my recent absence, which extended throughout the past session of this College year, it will be impossible for me to bring matters so fully to your attention as would be desirable.

Before I speak of the department work, permit me to thank you for the leave of absence granted to me in the early fall. I have appreciated highly the consideration which has enabled me to secure a needed change, and trust that I may be able to make some compensation in bringing renewed vigor to a closer attention to duty.

The Mechanical Engineering Department at present, though in urgent need of considerable equipment, is prepared to give, and we believe is giving, such instruction as is excelled by few if any institutions in the country. The earnestness and faithfulness which have characterized the assistants in this department was shown during my absence in their acceptance of the increased responsibilities of the time, and the excellent results attained in their work. I have been much gratified with the conditions I have found, both in what they and the students of the course have accomplished. I need hardly speak of the excellent services of Professor Jackson as acting Dean of the School of Engineering, of which you must be well informed. To his untiring efforts must be laid in large measure the successful carrying on of the work at a trying juncture.

In securing the services of Mr. Griffin as successor to Mr. Heisler, we have every reason to believe that the College, as well as the Department, has been fortunate. He comes to us with a previous training and experience that admirably fit him for the duties of his present position.

Permit me to call your attention to the following points bearing on the financial condition of the Mechanical Engineering Department.

It will be recalled that during the year 1896-7 items amounting to several hundred dollars were charged inadvertently to the Mechanical Engineering appropriation. After investigating this matter the Executive Committee sent to me a written communication promising that the department should be reimbursed. Later I was informed that the reimbursement could not be made at that time. When the distribution of funds was made at the opening of this College year these facts were not taken into consideration, nor were certain standing conditions recognized. You will pardon me if I here recapitulate these conditions. I believe that they cannot be fully understood, since they are evidently not appreciated.

The Department of Mechanical Engineering must equip

1. Its laboratories (for higher class work) not only for its own students, but for those of all the engineering departments, including Mining.
2. Its shops for all students of all classes, with the exception of those in Chemistry and Biology Courses.
3. Its drawing rooms for all students, with the exception of those in Biology.

Notwithstanding these facts, the appropriation to the maintenance fund of the Mechanical Engineering Department at the opening of last year was the smallest given to any department in the school. In consequence of these facts part of our laboratory work must be done at night, and the shops are greatly in need of appliances without which the efficiency of the work must suffer—a loss which you will note must be felt not only by engineering students but by nearly all in the College. (The shop fees cover the cost of materials, only.)

I do not wish to be understood to be making a complaint of the amounts appropriated to other departments. As Dean of the Engineering School it is my earnest desire to see them provided with sufficient means for growth. I appreciate, too, that you have done much in the past for the Mechanical Engineering Department, but, at the present time, it must be recognized that the appropriation put at the disposal is not sufficient for its proper continuance, and you would justly hold me responsible were I to fail to bring these facts to your attention.

It should be noted in connection with this subject that since 1894 the number of graduates in the Mechanical Engineering Course has been larger than in any of the other departments, it being thirty-two against thirty in the Electrical and fewer in other courses.

I respectfully ask your consideration of these points and hope that you may be able to put matters upon a more just and equitable basis. If nothing more can be done at the present time, permit me to request that my appropriation may be protected from accounts belonging elsewhere. During all of last year I economized in the effort to have a small balance at the end of the year for certain special purchases, only to lose it, through the charges improperly made to it, and already this year I find an item of $62.50 carried over from last year's salaries and charged to the Mechanical Engineering appropriation for this year.

Respectfully submitted,
LOUIS E. REBER.

State College, Pa., December 27, 1897.

XIV.—MILITARY DEPARTMENT.

To the President:

Sir:—Agreeably to letter of the Secretary of the College, expressing the requirements of the Executive Committee, rlativ to the annual reports, I respectfully submit the report of the Military Department, as follows:

The total number of students enrolled in the department this year has been 248.

Under the requirement that the three cadets of the graduating class who have shown the most proficiency in the military department should be reported to the Adjutant General of the Army, the names, H. H. Allen, T. Baumgardner and Chas. E. Mason, were so reported. These three gentlemen and likewise the names of John E. McCullough, Chas. W. Lawrence and Chas W. Hardt, were all reported to the Adjutant General of the State, with most honorable mention.

The aggregate present at drills during the year was 11,249.

The aggregate number of hours of practical instruction was 90.

The number of exhibition drills was 3.

The number of outdoor drills prevented by bad weather was 30.

The number of indoor drills was 31.

Under the head of target practice, there were 4 position and aiming drills, and, for every enrolled cadet, one sighting drill.

Under the head of gallery practice, the time provision was inadequate, and the handling of means for loading and reloading ammunition not practicable.

The practices were known-distance, five, at 100 yards, and one, at 200 yards.

The average number of shots per cadet was 5, each shot being entered in target record book.

Guard, with officer of the day, and officers of the guard, was mounted, but was not maintained, four times.

Under the head of theoretical instruction, the Freshman Class recited in drill regulations, Winter Term, and were graded according to proficiency, as obtains in other departments.

The aggregate number of students in this course was 78; aggregate hours of instruction, 36.

Under the limitations as to time, the U. S. Infantry Drill Regulations is the only text-book in use.

Upon drill days, for the half hour preceding drill, informal lectures were given by the commandant, to officers and non-commissioned officers, touching field and company officers' duties, and touching subjects of drill and cognate topics. Attendance was voluntary, but good, nevertheless.

For the period ending with Commencement, there was a daily average absence from drill of 39 per cent., all but 9 of which was due to excuses for literary, musical and athletic clubs and associations, as well as to a percentage of allowed absences common to all departments.

The 9 per cent. covered cases of sickness, or unavoidable causes, as well as a very small percentage of willful absenteeism, proper subjects for disciplinary treatment.

Under regulations adopted by the faculty, which went into effect with the Fall Term, by which sickness and unavoidable causes should be the only allowed reasons for absence, and by which, also, the handling of absences and excuses from drill has been confided to the head of the department, attendance at drill has been everything that could be desired.

The total of drills, per week and term, remains the same as heretofore. But the total of drills for each cadet has been reduced 50 per cent. When his company is scheduled to drill, by itself, or as part of the battalion, he is to be there.

Although averse to this reduction, we expect better results from a system under which drills are faithfully attended with full ranks, and an unchanging personnel, than can possibly be had when the rank and file are shifting and skeletonized.

Under the head of kind and amount of practical instruction, the Winter Term was devoted to the School of the Soldier, of the company and of the battalion, with the addition of Inspection, Guard Mount, and Physical Drill with Arms. The Spring Term was devoted to the same, with the addition of Outpost and Advance Guard. The Fall Term, to the same, omitting the Physical Drill with Arms.

In courteous compliance with the request of the Commandant, the Acting President associated with himself three other members of the Faculty, near the close of the Fall Term, to act as a committee, to decide which company of the four composing the College Battalion should acquit itself the best in a competitive drill. Their decision was in favor of "C" company, commanded by Cadet Captain White.

I again respectfully recommend that an appropriation of $100 be made for the purchase of officers' swords and for the equipment of a drum corps.

I deem it just to close this report with the following remarks taken from report of June 16th, last, which was made in accordance with the requirements of the War Department:

"Concerning the Military Department, its efficiency and progress, " the most important factors are believed to be the personal equa- " tions of President and Commandant.

"Such factors operate in all military garrisons to vary military pro-
" cedure, and more emphatically so, when so free to operate as in a
" non-military institution.

" For the military professor, it is essential that he shall have had
" experience in commanding men, and that he possess the faculty of
" steering his way thro' conflicting interests.

"The American spirit will seldom allow of a military government
" in any institution dependent upon outside voluntary support, and
" competing with other like institutions. But state and nation, be-
" lieving in the value of military instruction, have legislated for it,
" concurrently with instruction in agricultural and mechanical arts.
"So the military finds itself one department, with others, at this in-
" stitution, and with credentials second to none. Our own valua-
" tion of military instruction would prompt to the military depart-
" ment outranking all others. That being out of the question, then
" the question is, does the military department have an equal chance
" with other departments? It will not do to answer that question
" with a monosyllable. Each department is zealous for itself, and,
" more or less, lost to sight with other departments. The fact that
" but one department, and that the military, has an exemption com-
" mittee, whose original function of exempting the physically dis-
" abled, and the conscientiously scrupulous, from drill, has grown to
" excusing also musical and literary and athletic societies, has seemed
" cause for serious regret indeed. We have unavoidably felt injus-
" tice here. And, if students exert themselves, as many do, to be profi-
" cient in the military department, it is further example of injustice
" that that proficiency, equally with proficiency in other depart-
" ments, does not count in college standing.

" On the other hand, no other department has so many students
" enrolled. In no other department is the student required to have
" a distinctive suit of clothing. No other department has more
" prompt assembling of students, and that, too, without ringing of
" bell or other signal. None has better deportment during exercises.
" None is more in evidence when the college would put a good foot
" foremost. Touching the catalogued course for the military depart-
" ment, a revision is under consideration, with the idea that it is
" better to do a few things well, than a great many indifferently.
" No man can instruct so many in various military branches, each
" one of which might properly have a single instructor, and for
" which few or no hours are scheduled, even if there were the neces-
" sary text-books.

"The thing most to be desired is a better attendance at drill,
" which may be looked for the coming year, as the Faculty has just
" approved the recommendation of the Commandant that the causes
" for absence, with the exception of sickness and disability, men-

" tioned in answer to question 71, shall not apply upon the assigned
" drill days hereafter.

"Proficiency in the practical course of the military will hereafter
" be graded, also, and entered upon college records and reports."

Very respectfully,
Your obedient servant,
D. C. PEARSON,
Captain, 2d Cav.

State College, Pa., December 13, 1897.

XV.—MINING ENGINEERING.

To the President:

Sir:—Herewith I hand you a report of the work of the Department of Mining Engineering for the past year, the fourth in its history at this institution. In several previous reports have been stated the aims of the department, the facilities it enjoyed by reason of location and equipment and its needs for the future. In that for the year 1894 was described in detail the character of the instruction given to the students and the nature of their work; since then, neither of these has materially changed nor has there been any noticeable departure from the original schedule. The general status of the department is substantially the same as during the previous years, with the exception of the recent resignation of the Assistant Professor of Metallurgy and Mining Engineering. The most prominent facts in the internal affairs of the department is the lack of room in which appropriately to distribute the present possessions and the proffered contributions which can not be assured a fitting place. In our relations with the public as a Bureau of Information, or Experiment Station in mining lines, it has become evident that a greater appropriation is necessary in order fully to meet all demands upon the Department.

The Mining Bulletin has been regularly issued and cordially received. It continues to give selected abstracts from current mining literature and, judging from the expressions of approval from our constituency, we believe that these clippings serve better their interests than would scientific disquisitions, or brochures, upon technical subjects, for the latter, though they might be more creditable to our staff, would interest but fewer readers with each issue, and probably only those who are well able to procure special works upon the subjects. It is proposed, during the coming year, to issue with the extracts, short accounts of the extension of the compressed air and electric systems into the mines of the State, of the future of the oil and iron industries of Pennsylvania, of a proposed system of forms for the mine reports to Inspectors and of the possibilities of the electro metallurgic industries near our precious coal beds. Did the means of the department afford it, the issues of the Mining Bulletin should be 10,000 rather than 3,000, which is the extent of its present circulation. As the demand is growing without special effort on our part, the supply will soon have to be increased.

Since the establishment of the system of free lectures on mining topics in mining communities; thirty lectures have been given: during the past year, twelve. Invitations from Nanticoke, Pittsburg, Erie and other sections of the State have been declined with regret because the conditions were difficult to meet at the times specified. Others are now in contemplation. For their maintenance additional sums should be appropriated.

The laboratory facilities of the Department have been made use of by our citizens and, during the current year, thirty-eight analyses and assays have been made for various parties or public enterprises without charge or expert fee, except that in some cases a bill was sent for an amount to cover the cost of supplies consumed in making the tests. The same is true of the few field examinations made at the instance of some discoverer. If laboratory facilities could be afforded to reputable persons for research along lines which might seem to promise good results, without interference with the regular work, it might be the means of developing an *entente cordiale* with the establishments by which mutual benefits would accrue to undergraduates and to the industry.

In the economic geologic work of the State, the report upon brownstones was completed, printed and partly distributed. It has received favorable comment from both professional men and business men within and without the State. Assistant Professor T. C. Hopkins has devoted the past summer to field work on the clays and clay industry of the western part of the State. Personal examination was made by him of all the potteries, fire brick, red and buff building brick and paving brick industries in Westmoreland and Fayette counties and such portions of Greene, Washington, Beaver, Armstrong, Indiana and Cambria counties as border the Ohio and its tributary valleys. The examination and report on the building brick industries and clays of Allegheny county was entrusted to Mr. W. L. Affeleder of the Junior Class and the results of his work will be incorporated with the Report of the School of Mines. The reports on the summer field work of 1897 are well under way and it is hoped that they will be ready for the printer early in the coming year. The results of the examination have convinced us that the extent and importance of the clay industry of this State are much greater than was at first supposed from the information at hand when the work was at first entered upon. The importations of clay into the State from all sources aggregate so considerable a sum that it is hoped the College may have an allowance from which to provide machinery and equipment to make a more extended investigation afield, and to make practical tests in the laboratory. The clay resources of the State are sufficient to justify a well equipped department of ceramics for testing the different clays of the State and for training young men in the use of them.

In three institutions the State has given encouragement to this line of education with excellent results, and the Geological Survey of several other states of our Union has devoted time and money to this valuable natural resource. It is time that Pennsylvania should give aid to the encouragement of an industry in which so many of her citizens could engage with profit and reduce the importation from abroad. An excellent nucleus has been gathered here and machinery and furnaces for investigation in this line could well be established at slight expense. Lacking the necessary facilities at present for a continuance of the exploration and investigation on clays, it would be well temporarily to supend further work and take up another one of the building materials the examination of which our facilities will enable us to carry to a more satisfactory completion. Of these are suggested, slate, granite and its allied rocks, soils, limestones, limes and cements, bluestone, marble and serpentine.

The class-room exercises were conducted regularly as per schedule, the subjects taught being Geology, Mineralogy, Mining, Assaying, Metallurgy and Ore Dressing and Coal Washing. There has been no interruption to the work during the year and the results have been eminently satisfactory. It is very gratifying to be able to report the immediate engagement, in positions of responsibility, of the graduates of the class of 1897.

Geology.—The class work included instruction to members of the upper three classes of the College in six different courses. One student is pursuing special work in Geology. The coming year will witness the addition of a course in Petrography which will consist of twenty conferences in the micro structure of ordinary rocks encountered in metalliferous regions. The section cutter and polisher has been put to service in the preparation for this course.

In Mineralogy the classes have been seriously inconvenienced by the insufficient room afforded them in room No. 120. While it may be ample for the large class in Geology and a few cases of specimens, it is not sufficient to give space for the number of operators in blow-piping who are seated at tables with numerous appliances. Unless separate quarters are furnished for the Museum collections, the coming class may of necessity be divided into sections.

Mining.—Classes have devoted increased attention to the improvements in machine installation, electric and compressed air, and manufacturers have been liberal in their contributions of working drawings and catalogues. An inclined tramway, an electric haulage train and motor, safety lamps and testers, besides numerous blue prints and lantern slides have been added to the illustrative material of the department.

Coal Washing and Ore Dressing.—Conducted by lectures only, great dependence is placed upon the laboratory and working appliances in our possession and it is hoped that in the very near future a suitable building may be provided for an enlargement of the plant. This branch of the mining engineer's calling is of rapid growth and the student must keep pace with the demand for a conservation of Pennsylvania's main natural resource. The lectures delivered upon this subject here will soon appear in printed form, no attempt having as yet been made elsewhere, to furnish a text-book upon the subject.

Assaying.—Insufficient room and equipment has rendered it necessary to divide the class in this subject and it is earnestly hoped that the near future will see a more extended equipment in this direction, thus allowing for a more extended course.

Metallurgy.—The class room work in this subject has been particularly efficient and it is hoped that for the coming year an equally competent instructor in the science may be secured. Until his successor is appointed, the work of Assistant Professor H. H. Stock will be assumed for the coming year by other members of the present force. It would be of material benefit if an harmonious redistribution of the subjects taught in this branch of the Department could be effected so as to equalize, during the three sessions of the year, the work of the instructor who now has but one class in the Fall Session and Five in the Spring Session. It is keenly felt by the department that the inability to maintain a laboratory in chemical technics as applied to the metallurgy of fuels, the manufacture of coke and the examination of refractory materials is a serious deficiency, and it is the sincere wish that such a supplementary aid may be afforded theoretical instruction in the class room. The equipment now installed in the Mechanic Arts building is of great service in this direction as far as it goes. The gratifying results obtained from the use of the models of blast furnaces made to our order from approved drawings, prompt us to a request for others to illustrate coking and zinc metallurgy.

The Summer School of Practical Mining was conducted this year in the Schuylkill Valley, the class having been particularly fortunate in its reception by the superintendents of mines and division superintendents for the Philadelphia and Reading Coal Company, while to its general manager, R. C. Luther, we are indebted for many special facilities for the examination of particular problems. Shamokin, Ashland and Shenandoah were the headquarters during the trip, and from these points the members of the class set out to the neighboring properties. No attempt was made to go through the entire mine in each case and to inspect the whole gamut of its operations, but there was selected for each property one item of special interest or development which was thoroughly studied; thus one mine was inspected for its compressed air plant; in another, a dam or bulkhead was examined while in process of construction; in another, the haulage machinery was examined; and in yet another, were visited the rooms whose excavations were being filled with the waste coal dust. Notes taken by the students were later submitted for inspection and correction. It is expected to hold the coming Summer School trip in Jefferson county at the famous Soldier Run mines.

The department has a well selected library of technical works, but it is desired that more works of foreign specialists be procured for the use of students who are engaged in special investigations. The year's purchases for the library aggregate $85.27, exclusive of the periodicals maintained in the reading room.

For the coming year it is hoped that allowance will be made for procuring additional collections in typical minerals, common fossils and lithologic apparatus; for the preparation of more lantern slides; for the construction of other models in metallurgy, and for a few relief maps, which are a great aid in the study of physiographic geology. If these maps should prove as attractive as is the relief map of the State to the body of students, their instructional value will extend far beyond the comparatively small classes in geology. A portable camera and developing outfit will be of service to those having the Summer School in charge and to those making the economic surveys.

In closing I wish to express my appreciation of your continued and effective interest in the affairs of the department.

Respectfully submitted,
MAGNUS C. IHLSENG.

State College, Pa., December 27, 1897.

XVI.—MODERN LANGUAGES.

To the President:

Sir:—The aims and work of the Department of Modern Languages have been so thoroughly treated in the last two reports that a repetition of the details is at this time not deemed necessary. A few features of our past year's experience and of our present condition and needs are worthy of notice.

There is a marked improvement in the general tone and preparation of the last in-coming class, although the "English as she is spoke" still exhibits marked deficiencies.

The students on the whole are to be congratulated for their increasing interest and material progress in foreign language work. The failure of a student repeating the first term's work in a foreign language, previously pursued for one year and passed at a certified grade of 70 in another institution, lends testimony in some degree to the excellent grade of work done by our students and to the high standard of the department.

The admission of four ladies into German and one into French as special students taking these subjects only is fully warranted by the excellent record made by them, and by the salutary influence of their presence upon the respective classes to which they belong.

A word or two about our "coaching" system may not be amiss. Notwithstanding the special attention which the weaker students among the Freshmen receive in all recitations, there are always from ten to twenty per cent. of the entire class who for some reason or other do not keep pace with their class-mates and who therefore require special assistance. Deeming it unwise to retard the progress of the many to the advantage of the very few, we organize within four or five weeks of the close of the term what is called a "coaching" class, and appoint a competent tutor to conduct the assigned "quiz" and drill twice a week outside of regularly scheduled hours. Attendance is entirely voluntary, but nearly all who are advised and others in good standing are glad to embrace this opportunity of being helped to a higher standing. Improved results have repeatedly warranted this system, inasmuch as the number of conditions incurred has been reduced about twenty-five or fifty per cent.

The greatest need of the department is printed or typewritten copies of examination questions. It must be obvious that putting text and questions on the boards of two large rooms, where from 75 to 100 students are to be examined is out of the question; that the use of the text-book is inexpedient, and that mimeographic copies of the text of a foreign language, even in a good hand (the method now used) are at best a disadvantage to the student. While under the present circumstances we do not presume to ask for a first class duplicating typewriter—an appliance very much needed—we would request some arrangement by which stenciled copies of the French and German examination question papers could be made and placed in our hands for manifolding within a short time of each examination.

Maps of Germany and France, showing political boundaries at various periods of their history, are very much needed, as nothing of the kind is available here for class use. It is requested that this receive your earliest consideration.

Whatever success has attended the efforts of the department is due to your cordial co-operation in furnishing ample slate board surface, in providing larger and better accommodations for the classes in French, in purchasing needed books, and in retaining the efficient services of Mr. Foster.

Respectfully submitted,
CARL D. FEHR.

State College, Pa., December 25, 1897.

XVII.—PHYSICAL EDUCATION.

To the President:

Sir—I have the honor to present to you a report from the Department of Physical Education. In this, my first one, I shall endeavor to outline the work as it has been conducted during the one year of my residence, noting its deficiencies, for to no one are these more patent than to myself, as well as those points in which the hoped for results have been reached.

Its aim has been continually to secure the greatest good for the greatest number, as best it could with the limited means at our command. The foundation of all exercise and its proper direction is in careful, thorough and systematic examinations of the individual. This portion of the equipment, as rapidly as possible, has been increased until it is now practically complete, and not only are accurate measurements taken of the muscular development, lung capacity and strength of groups of muscles, but a searching study of the lungs and the heart, including its valves, sounds, size and position, is made, and the outline transferred to a permanent chart, annotated at the actual observation points. When latter examinations are made these charts are applied to the new outlines, comparisons made and the least change for better or worse is instantly detected and met.

Our sphygmogram gives us the arterial condition, and a close microscopical examination of the blood reveals to us disorders not otherwise demonstrable. And I may add that this last procedure, though most important, is not, to my knowledge, done in any other college in the country. In short, there is very little relative to the student which is not known and put on permanent record.

Owing to the limited outfit for practical in-door work and various other causes which we have not been able yet to remedy, the carrying out of the lessons learned from this system of examination has been rather difficult but is becoming easier as time goes on, and more effective.

While acting as an agent for improvement up to its limit, this Department has still another function and one often overlooked. It is that of a safeguard against accident. Therefore, although in actual gymnastic work there is not yet the hoped for advance in perfecting the physical condition to our satisfaction, it is nevertheless doing thoroughly that which is equally as important in that, by the exact and complete knowledge obtained concerning the individual, the student who is so unfortunate as to posses a faulty organism is informed of it, prescribed for and prevented from taking part in those pastimes and sports which would be harmful and might be fatal to him. Of course, the goal toward which we are striving is regularity of prescribed exercise (which is now given as fully as is practicable), but since there is in every American collegian an instinctive "play impulse" which prompts and compels him to take a certain amount of exercise, he will take it and in whatever way he may. The way selected may be and often is most deleterious to him, and, if ignorant of his local weakness or unwatched, may lead to dangerous results. Granting that we are not doing all that we could wish to build up the under-developed but sound man, this safeguard, negative though it be, and its paramount importance to the future of the man must neither be lost sight of nor underestimated.

There are but two causes which can induce students to regularity of exercise—compulsion and enthusiasm. If compulsion is inexpedient, then enthusiasm is necessary. To create enthusiasm for gymnastic work it must be made attractive; to be attractive it must be varied and convenient. And right here it is that this department is seriously handicapped, both in doors and out. Our apparatus and hygienic equipment is not sufficiently varied nor convenient to attract or encourage. Dressing rooms, lockers, baths and drying rooms are our crying need as well as facilities for other and new forms of exercise.

The question of further fitting up and adapting the Armory, which is now used as a gymnasium, has been carefully considered and there are many reasons why such a move would not be the most expedient, aside from the fact that for much less than twice the expense a satisfactory building for the purpose could be erected and equipped.

That one room must serve the double purpose of drill hall and gymnasium necessitates frequent clearing of the floor and therefore movable apparatus would prevent it from ever being convenient, whatever might be done to it. The overhead construction is such that suspension is difficult and might easily approach the danger line. The putting in of a track gallery, a necessity to every gymnasium, is costly, and when all improvements have been completed we should still have but one room for all varieties of work—No base ball cage, no pool, no bowling alley, few of those things which attract students, and in fact not at all that for which the outlay had been made.

Out of doors we are in an equally poor condition. There are no convenient baths nor dressing rooms on Beaver Field; the track is not safe for bicycle riding nor properly built for running and almost the entire field must be turfed before it is safe for athletics.

In the meantime, by gradual additions and improvements the department is increasing its efficacy and slowly realizing that purpose for which it has been created, namely, to perfect the physical, side by side with the mental education.

In conclusion, I wish to take this opportunity of expressing my very sincer appreciation of the interest and helpful co-operation of both yourself and the Board of Trustees, and to thank you all, together with the members of the Faculty, for the uniform and continued kindness which I have received. I am, sir,

Sincerely yours,
S. B. NEWTON, M. D.

State College, Pa., December 21, 1897.

XVIII.—PHYSICS.

To the President:

Sir:—There has been no change in the general scope and arrangement of the work in this department since my last report, and the several courses of lecture room and laboratory work described in the last catalogue, pp 60-62 (hereto attached "A'), have been given during the year according to the schedules. The additional apparatus purchased has enable us to make some improvements in parts of the work.

The number of students, by terms and courses, has been about the same as during the previous year (See "B", hereto attached). An average of 59 students in class-room and 22 in laboratory, for two instructors, is probably as large a ratio of students to instructors as in any of the departments of the College in which the work is comparable in character with this as regards requisite work of instructors.

I can but regret that the appropriation of '96-7 was so small and so much of it necessarily taken for other purposes than equipment. There are many fixtures and facilities still unprovided about the building and much apparatus greatly needed not yet obtained. I had hoped that the appropriation might be at least as large as that of the preceding two years, which would have made us, when expended moderately provided for the work as outlined in the various courses, with the present number of students.

In accordance with the authorization given by the Board of Trustees last June, the independent electric light plant of the Physics Department has been transferred to the Engineering Departments, and the large and well-lighted half-basement room in the Physics building, needed for a laboratory, is now available. The fitting up of this room for a laboratory has not yet been done, but will probably be completed during next session.

The organization, purposes and character of the work in this Department have been given in former reports: as in that of 1895, from which I here introduce one sentence:

"The work of the Department of Physics is arranged with reference to a three-fold purpose, or function: (1) to provide a good outline of principles, and appropriate laboratory work for students in the General Science Course and other courses in which Physics, however important, is not a principal subject: (2) to provide a more complete course, stronger especially in mechanics, heat and electricity, for the students in the Engineering Courses; and (3) to provide a full and advanced course for those who wish to make physical and mathematical studies principal subjects."

The course of work for purpose numbered one above covers systematically, though briefly, the subjects usually designated by the term Physics, namely, Mechanics, Sound, Light, Heat, Magnetism and Electricity, together with an elementary Laboratory Course in Physical Measurements.

This is intended to give to the general student that knowledge of the world of physical phenomena which is indispensable to every educated or thinking person, and to be of especial value to the student of agriculture, chemistry, biology, or medicine. This work has been for some years past mainly or entirely under the able and thorough conduct of Assistant Professor Garver. Our equipment more nearly provides for its requirements than for either of the other two courses. I believe that this course as now given compares very favorably with the Junior year work of the better American colleges in other than engineering and mathematical courses.

The course for purpose (2) above is not in actuality what it was intended to be, a complete Course in Physics. In none of the Engineering Courses are all the branches of Physics included. But to such subjects as are included, more extended and advanced treatment is given than in course (1). The incompleteness of this line of work, it seems to me, is to be deplored, and that, if possible, all engineering students should have a systematic, moderately extended and advanced, complete course in Physics.

Another question concerning this course of work is continually recurring, shall the branches of physics that are included be taught with a view to a scientific and logical grasp of the subject, or shall the method of treatment be to pick out those points of most frequent use in technical studies and dwell upon and emphasize them until the student learns them, whether or not he have a scientific knowledge of the subject. The latter method, however strong the pressure toward it may be, seems to me rather adapted to such science teaching as may be in trades schools than proper for a technological institution, or courses.

The third course, for purpose (3) above, given in this department, suffers somewhat from having to use, unavoidably, part of the work of course (2). Thus it is not quite what I would regard as an ideal course for the purpose. But to make this work entirely independent of the line of work in course (2) would require a multiplication of classes quite impossible under existing circumstances; and perhaps not warranted, even if possible, until called for by a greater number of students, or fuller provision for its special needs.

These subjects and others, I shall be glad to consider with you more fully than can readily be done in such a report as this, whenever you may desire to give them such consideration.

Respectfully submitted,
I. THORNTON OSMOND.

State College, Pa., December 27, 1897.

"A."

This course is designed not only to furnish an extended training in various branches of Physics and closely related physical sciences, which are properly included in a complete college course, whether general or technical, but to provide advanced instruction for those who wish to become specialists in this field. It is primarily intended to be distinctly scientific in its nature and but subordinately technical. It deals principally with pure science and only secondarily with its technical uses. Its purpose is, first of all, intellectual training as of chief importance; and, second, knowledge and skill pertaining to the great body of physical phenomena and principles, which knowledge and skill may either immediately or very readily be put to use in a multitude of the arts and industries founded so largely on physical laws.

The distinguishing feature of the course is the continuous and extensive study of the various branches of Physics as shown in the schedule of studies and practicums. Pure Mathematics, also, are studied as fully as the course requires, with provision for advanced special work in that subject. Another prominent subject is Chemistry, which is required through three sessions, with provisions for electing an additional year of chemical work in both the lecture-room and the laboratory.

While Physics is a required major subject in the last two years, considerable variety in the course is made possible by the elections provided. Thus, Chemistry required in the Sophomore year may be continued through the Junior year, or, if mental and civic sciences are preferred to so extended a course in chemistry, these may be elected for the Junior year and with the required studies of the Senior year make a two years' course in these subjects. Or again, whichever election may have been made in the Junior year, another may be made in the Senior year between the continued study of Physics as a pure science and a year's study of electrotechnics.

These elections permit no capricious selection of studies; each is for a year of work, which, in each case, will be part of a two years' course for a definite purpose.

The studies in Physics included in this course are as follows:

(1) Elementary Dynamics (Mechanics), the last two sessions of the Sophomore year. Vibratory Motion, one session.

These two subjects are not only introductory but are fundamental to all the succeeding work in Physics, and are taken by all the students in the various Engineering Courses and in the Courses in Mathematics and in Physics.

(2) A course covering the elements of Sound, Heat, Magnetism, and Electricity.

This course, also, is taken by all Engineering students, as well as those in Mathematics and in Physics.

(3) A more advanced course in the Theory of Electricity, the Theory of Heat, and the Theory of Light. No student in any of the Engineering Courses takes any part of this work. Those in Mathematics take part of it; those in Physics, all.

(4) An elementary laboratory course in Physical Measurements.

A part of this is taken by students in the Engineering Courses; it is taken completely only by those in the courses in Mathematics and in Physics. It includes the use of instruments of precision in the measurement of the fundamental quantities, space, time, and mass, in measurements of other dynamical quantities, and in heat, electricity, and light.

(5) A laboratory course in Electrical Measurements: taken by students in Electrical Engineering, and, more extended, by those in Mathematics and in Physics. It includes the use of various instruments and methods of measurement of the important magnetic and electric quantities.

(6) Special work of a more advanced and difficult nature in Physical (including Electrical) Measurements.

(1), (2), and (4) require a knowledge of mathematics through Plane Trigonometry; (3), (5), and (6) through at least the elements of Analytic Geometry and Calculus.

Courses (1), (2), and (3) are illustrated by experimental lectures; and the laboratory courses (4) and (5), pursued as much as may be in relation with them add much to the experimental character and verification of the class-room courses.

Nearly all the work done in the laboratory is quantitative in character, and is designed to acquaint the student with physical instruments of precision and the general nature and methods of accurate quantitative work in applied physics and in physical research.

The above outline gives the full work offered in Physics in the course in Physics; and taken, in greater part, in the course in Mathematics, and partly in all the Engineering Courses.

For students in the General Science, Latin Scientific, and Classical Courses, the courses in Agriculture, Biology, Chemistry, and others, the Department of Physics carries on two other lines of work.

(7) A course extending through the Junior year and covering systematically, though briefly, the subjects usually designated by the the terms Physics, Mechanics, Sound, Heat, Light, and Electricity.

(8) An elementary laboratory course pursued as much as may be in relation with course (7) and embracing measurements in the subjects of that course.

Courses (7) and (8) are intended to give to the general student that knowledge of the world of physical phenomena which is indispensable to every educated or thinking person; to the student of agriculture the ability both to read the works of agricultural science more profitable and to observe and use more intelligently the physical agencies so universally and vitally concerned in all his work; to the student of chemistry a body of knowledge absolutely essential in his specialty; and to the student of biology a knowledge of the agencies which universally and ceaselessly environ and condition (if they do not constitute or control) every vital action.

Students preparing for the study of medicine will find in courses (7) and (8) quite as full and thorough a study of Physics as is required by the best medical colleges, all of which either already require or are likely soon to require this subject.

"B." (From Previous Report.)

Summary of Students Referred to in Above Report.

Session.	Classroom.	Laboratory.
Winter,	37	34
Spring, (39X2+9),	87	12
Fall,	52	19
	—	—
Mean,	59	22

XIX.—PSYCHOLOGY AND ETHICS.

To the President:

Sir:—In reporting the work of the department of Philosophy, I wish to express a sense of gratitude for the helpfulness and increased efficiency which have resulted from your efforts in granting funds for a material and literary equipment. "Tools" are not an education in themselves, but they are an indispensable aid thereto; and I bespeak your continued support for our present and growing needs.

Two more or less distinct lines of work are carried on by the department.

First: The instruction required in the General and Latin Scientific Courses, embracing psychology, logic, ethics, history of philosophy, etc. Some of these subjects have been incorporated into other courses also; and it is worthy of most serious consideration whether all collegiate courses should not include in their respective outlines of required studies, the two subjects, at least, of psychology and ethics.

Second: A specific course in Philosophy, in which psychological and educational subjects have a determinative weight. The guiding principle in this part of our work is to provide a thoroughly technical course in these branches, pursuing them for a sufficient length of time and with such a regard for their proper correlations as to secure good results. Considerable periods devoted to practicums enables the student to apply and assimilate the instruction of the class-room. In psychology, he makes use of the laboratory equipment to illustrate the conclusions of the science itself, and in addition brings experiment to bear upon some one problem, the results of which become peculiarly his own. In other subjects, like those of ethics and philosophy, where experiment is not applicable, the student utilizes the practicum to acquaint himself with the writings of the authors studied. Digests are made, comparisons called out, to the end that the critical powers may be strengthened.

The carrying into effect of the two lines of work above detailed necessitates a considerable number of distinct classes. The total number of students pursuing the Course in Philosophy is not large; but that fact does not alter in the least the energy demanded of the instructor, the thoroughness of his preparation, or the standards set for his work. Many colleges are systematically specializing these branches by placing them in the hands of three, five or seven men, and doubtless like steps will be taken here at the earliest possible moment.

The plan for co-operative work among the psychological laboratories of the United States, now under consideration by the American Psychological Association, will if adopted, and so far as our facilities permit, be given attention. It is thus hoped to prevent some reduplication of the more costly apparatus and secure uniform experiments upon a wide range of problems, though with varied results.

The needs of the department remain substantially as heretofore. The small amount available for the current year will, however, provide several important aids to our work, add a few indispensable books and pamphlets, thus enabling us to broaden practical work in psychology. Our total laboratory equipment makes it possible now to carry out the tests and experiments upon sensation and perception treated in works of the grade of Sanford's Manual; as well as upon certain phases of association, memory, feeling and will. Our greatest need lies in the direction of apparatus to apply the graphic method and in combination therewith the accurate determination of time intervals. This would involve an additional expenditure of several hundred dollars. It is hoped that in the near future this and other needs may be met.

A matter of importance for which immediate aid ought to be rendered is the binding of periodicals. Psychology as a science is growing largely in periodicals and pamphlets. Many laborers are contributing to the statement and solution of the problems, and these necessarily appear not in systematic text-books but in Journals and memoirs wherein detail and accuracy can be embodied. Monographs are now written, based upon the most painstaking and persistent experiments, where previously a line sufficed to express what was known of the subject. I would respectfully urge, therefore, that the American Journal of Psychology (the complete volumes of which we are fortunate in possessing), and the Psychological Review, be bound and placed upon the shelves of the Library, so that the students' reference thereto may be facilitated.

I have but feelings of gratitude to Trustees, colleagues, students, and to you, sir, for the courtesy and uniform helpfulness shown my work.

Respectfully submitted,
ERWIN W. RUNKLE.

State College, Penna., December 23, 1897.

XX.—SUB-FRESHMEN OR PREPARATORY CLASS.

To the President:

Sir:—The work in the Sub-Freshman or Preparatory class has been prosecuted in accordance with the plans suggested in our last report. Thoroughness has characterized the work. The general attitude of the students is excellent.

We believe that the purposes for which the class is maintained are being largely attained. Twenty-seven students completed courses last June. Twenty-two were admitted to the Freshman class. The Heads of the various departments have reported that these students, as a rule, are doing satisfactory work. The results of the examination held at the close of the Fall Session show that not a single student from this department, so far as I have been able to learn, lost his standing in class, and the Head of the Department of Mathematics reported that the number of men conditioned from the Preparatory Class was exceptionally small, a result, no doubt, as gratifying to you, Mr. President, as to the instructors of this department.

At the beginning of this year, thirty-four students were admitted to this department, thirty-two in the General Science Course, and two in the Latin Scientific.

It is too soon to estimate fully the results of the change in the course of study recommended in our last report and adopted by the Faculty and Board of Trustess, viz., that Physical Geography be made a requirement for admission, and that two full sessions be given to Elementary Physics; but it is believed that the change will be highly satisfactory.

We wish to renew two recommendations made last year and to add a third. First, that room 114 be reseated. The seats with desks should be replaced by settees having an arm rest for writing. The seats now in use are conducive to the formation of improper habits of sitting and standing. The value of correct positions cannot be emphasized too strongly.

Second. The efficiency of the work in Elementary Physics would be greatly increased if enough money were appropriated to purchase necessary apparatus. It is well-nigh impossible to teach the subject properly with the apparatus at our disposal. We recommend, therefore, an appropriation of two hundred dollars for this purpose.

Third. It is recommended that the course in Industrial Art and Design be shortened one hour per week. Previous to the present session (Winter, 1898) the Sub-Freshmen have been scheduled for four hours per week in Freehand Drawing. This term for the first time they are given five hours per week. We advise the old schedule of four hours per week and that one hour be given to an English practicum. The weakness of college students generally in English has been demonstrated again and again.

In order to determine the amount and kind of reading that had been done by the present members of the Sub-Freshman class, we asked during the Fall Session the following questions: First; How many volumes have you read of (a) History, (b) Biography, (c) Travel, (d) Science, (e) Fiction, (f) Miscellaneous? Second; Name the books read during the past year. The utmost freedom in answering was allowed. The only exception was that no book should be reported that had been studied as a text-book. We are satisfied that the answers included many books not properly read, books that had been read only in part or in a very superficial way, and that many books termed volumes were but extracts found in school readers, etc. The maximum reading was desired, however, and the request was to report books read even superficially. Notwithstanding this freedom, the report shows that in a class of thirty-two members, thirteen had never read a volume of history, fourteen had never read a volume of biography, and twenty-three had never read a volume of travel. All had read some fiction. The total number of volumes of history reported as read by the class aggregated one hundred twelve; of biography, ninety-four; of travel, sixty-seven; of science, forty-three; and of fiction sixteen hundred eighty-three. The list of fiction contains many worthy books, many that are positively harmful, and more that are absolutely worthless. We do not consider this class below the average senior high school or preparatory class, and a like test with other classes would, we are convinced, reveal similar conditions. This test, imperfect as it has been, is sufficient to warrant the suggested change of schedule. An English practicum of one hour per week throughout the entire year under a competent instructor would accomplish much in leading students to make wiser and better selections of books and in establishing habits of careful and systematic reading.

Respectfuly submitted,

MARTIN G. BENEDICT.

State College, Pa., December 31, 1897.

REPORT OF THE TREASURER.

FROM JULY 1, 1896, to JUNE 30, 1897.

State College, Pa., January 26, 1898.

To the Board of Trustees of The Pennsylvania State College:

Gentlemen: The following report of the Treasurer of The Pennsylvania State College is respectfully submitted. The accounts are arranged under the following titles, corresponding to the Ledger headings in the College books of account:

1. The College general account.
2. The United States Account, Act of 1890.
3. Eastern and Western Experimental Farm, interest account.
4. State appropriation of 1887.
5. State appropriation of 1893.
6. State appropriation of 1895.
7. Experiment Station general account.
8. Experiment Station, United States act of 1887.

THE COLLEGE GENERAL ACCOUNT.

Dr.

To balance in hands of the Treasurer June 30, 1896,	$1,037 69	
To amount received from land fund,	30,000 00	
To amount received from proceeds of notes discounted,	21,600 00	
To amount received from students and all other sources,	24,367 71	
	$77,005 40	

Cr.

By cash paid for College expenses,		$78,946 66
To balance due the Treasurer June 30, 1897,	$1,941 26	
	$78,946 66	$78,946 66

UNITED STATES ACCOUNT, ACT OF 1890.

Dr.		
To balance in hands of Treasurer, June 30, 1896,	$18 90	
To amount received from Treasurer of U. S.	22,000 00	
Cr.		
By cash paid for College expenses,		$21,931 44
By balance in hands of Treasurer June 30, 1897,		87 46
	$22,018 90	$22,018 90

EASTERN AND WESTERN EXPERIMENTAL FARM ACCOUNT.

Dr.		
To balance in hands of Treasurer, June 30, 1896,	$2,065 76	
To amount received from State Treasurer,.	1,020 00	
Cr.		
By balance in hands of Treasurer June 30, 1897,		$3,085 76
	$3,085 76	$3,085 76

STATE APPROPRIATION OF 1887.

Dr.		
To balance in hands of Treasurer, June 30, 1896,	$169 89	
Cr.		
By college bills paid,		$19 35
By balance in hands of Treasurer June 30, 1897,		150 54
	$169 89	$169 89

STATE APPROPRIATION OF 1893.

Dr.		
To balance in hands of Treasurer, June 30, 1896,	$65 38	

Cr.		
By College bills paid,		$2 50
By balance in hands of Treasurer June 30, 1897,		62 88
	$65 38	$65 38

STATE APPROPRIATION OF 1895.

Dr.		
To balance in hands of Treasurer June 30, 1896,	$3,806 02	
To amount received from the State Treasurer,	53,827 32	
Cr.		
By College bills paid,		$49,961 21
Balance in hands of Treasurer June 30, 1897,		7,672 13
	$57,633 34	$57,633 34

EXPERIMENT STATION, GENERAL ACCOUNT.

Dr.		
To balance in hands of Treasurer June 30, 1896,	$871 31	
To amount received from notes discounted,	1,500 00	
To amount received from analyses of fertilizers,	8,541 50	
To amount received from all other sources,	4,873 16	
Cr.		
By cash paid bills and expenses of Station,		$13,469 54
Balance in hands of Treasurer June 30, 1897,		2,316 43
	$15,785 97	$15,785 97

EXPERIMENT STATION, U. S. ACCOUNT, ACT OF 1887.

Dr.		
To balance in hands of Treasurer June 30, 1896,	$31 25	
To amount received from Treasurer of U. S.,	15,000 00	

Cr.

By cash paid bills and expenses of Station,		$15,490 93
Balance due Treasurer June 30, 1897,	459 68	
	$15,490 93	$15,490 93

SUMMARY.

COLLEGE ACCOUNTS.

Balance on hand July 1, 1896,	$7,163 64
Total received to June 30, 1897,	152,815 03
Total,	$159,978 67

Cr.

By amount expended to June 30, 1897,	$150,861 16
Balance on hand June 30, 1897,	9,117 51

EXPERIMENT STATION.

Balance on hand July 1, 1896,	$902 56
Total received to June 30, 1897,	29,914 66
Total,	$30,817 22

Cr.

By amount expended to June 30, 1897,	$28,960 47
Balance on hand June 30, 1897,	1,856 75

TOTALS.

Total receipts including balance on hand July 1, 1896,	$190,795 87
Total expended up to June 30, 1897,	179,821 63
Balance on hand June 30, 1897,	$10,974 26

JOHN HAMILTON,
Treasurer.

CLAYS AND CLAY INDUSTRIES

OF

PENNSYLVANIA.

I. CLAYS OF WESTERN PENNSYLVANIA (IN PART).

DESCRIPTION OF THE CLAYS AND CLAY INDUSTRIES IN THE OHIO, MONONGAHELA, YOUGHIOGHENY AND CONEMAUGH RIVER VALLEYS IN PENNSYLVANIA AND THE ALLEGHENY VALLEY AS FAR UP AS KITTANNING, INCLUDING ALLEGHENY, WESTMORELAND AND FAYETTE COUNTIES AND PARTS OF BEAVER, WASHINGTON, GREENE, INDIANA, ARMSTRONG AND CAMBRIA COUNTIES.

BY

THOMAS C. HOPKINS,
Assistant Professor of Economic Geology in The Pennsylvania State College.

APPENDIX TO THE ANNUAL REPORT OF THE PENNSYLVANIA STATE COLLEGE, FOR 1897.

VIRTUE
LIBERTY AND
INDEPENDENCE

State College, Pa.,

April 25, 1898.

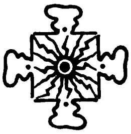
Sir: I have the honor to submit herein my report on the clays and clay industries of part of western Pennsylvania, prepared according to your instructions. The field work was done during the summer vacation of 1897 and the office work at intervals during the college session now in progress. There is also included the report on the clays of Allegheny county, prepared under my directions by Mr. W. L. Affelder, a member of the Junior class in the college.

Permit me to thank you for your kind advice and encouragement in all phases of the work.

Respectfully submitted,

T. C. HOPKINS.

To the President of The Pennsylvania State College.



PREFACE.

The following report on the clays and clay industries of western Pennsylvania is the second one of the economic reports on the natural resources of the State, published by The Pennsylvania State College. The first one, published in 1897, was on the Brownstones of Pennsylvania.

The present report covers only one season's work and only a limited area of the State; but it is thought best to give the results of each year's work as promptly as possible in order to increase their value to the region under discussion. After the other sections of the State have been explored in a somewhat similar manner, we hope to embrace all the results of more or less general interest in monographs or final reports treating of both the practical and the scientific problems involved.

The present report contains such data as are thought to be of value to the trade and to the reading public, on the clay industry of one of the greatest manufacturing districts of the world.

It will no doubt be a surprise to many persons to see the extent to which the clay industries have been developed in western Pennsylvania. We are all familiar with the great commercial development of the coal, oil, iron and glass industries of the Pittsburgh region, but frequently overlook some of the less important but still quite extensive industries. The investigation shows that a capital of nearly seven million dollars is invested in the varied clay industries about Pittsburgh, of which more than three million dollars is in the fire-clay industry. The value of the annual output of material is nearly four million dollars, more than 50 per cent. of the capital invested. There are 139 companies, employing 4,403 men.

The commercial advantages accruing to the State from this home industry as an aid to the other manufacturing industries is much greater than would appear at first glance. Great as it is, however, it might with profit be developed still more extensively (1) by using more of the fire-clay parting in the Pittsburgh coal seam which now forms numerous large heaps of waste throughout the region; (2) by manufacturing larger quantities of high grade building brick, such as buff, pressed, vitrified and variegated brick; (3) by the manufacture of enamelled or porcelain brick; (4) by increasing the production of paving brick.

That some portions of the region are described with greater fullness of detail is partly due to their greater commercial importance as centres of the industry, partly because they are typical and the description applicable to surrounding localities, and partly due to the fact that some manufacturers more freely gave information in regard to their works, and facilitated in every way explorations of their mines and factories.

While it would not be possible to enumerate all the parties to whom we are indebted for courtesies and assistance rendered, some who bestowed special favors should be named. Hon. J. B. Hammond, of Bolivar, not only kindly accompanied me to all parts of the large property owned by Reese, Hammond & Co., but to all the neighboring mines, and prepared at his own expense the excellent illustrations of the mines and works at Bolivar, besides giving valuable information concerning the industry in other portions of the State. Mr. L. O. Livingstone, of New Brighton, kindly accompanied me to all the mines and works in Beaver valley. To Mr. R. R. Hice, of Beaver, I am indebted for information concerning the local geology and distribution of clays in Beaver county. Mr. A. F. Smith, of New Brighton, and the Hon. George McNees, of Kittanning, gave valuable information concerning local interests. The Wick China Co. furnished the excellent views illustrating the processes in china making.

The Clay Worker, of Indianapolis, kindly loaned numerous electrotypes of the brick works and clay mines at Pittsburgh. The Chambers' Bros. Co. of Philadelphia; the Henry Martin Brick Mfg. Co., of Lancaster, Pa.; E. M. Freese & Co., of Gallion, Ohio; the Bonnot Co., Canton, Ohio; the American Clay Working Co., Bucyrus, Ohio, kindly loaned electrotypes of machinery used in illustration.

It is to be regretted that time did not permit the examination of the upper part of the Allegheny valley area and thus render complete the river valley areas of the western part of Pennsylvania.

T. C. H.

State College, Pa.

CONTENTS.

Page.

Letter of transmittal, 3

Preface, 5

Chapter I. General features of clays, 13
- composition, 13
- origin of clays, 14
- properties, 15
- varieties, 15
- uses, 16
- value, 17

Chapter II. Potteries and allied industries, 18
- earthenware, 18
- stoneware, 18
- yellow and Rockingham ware, 22
- white ware, 23
- hollow ware, 24

Chapter III. Pottery industries of western Pennsylvania, 24
- 1. In the Monongahela river valley, 24
  - New Geneva, 24
  - Greensboro, 25
  - Pt. Marion, 27
- 2. Kittanning-Ligonier, 28
  - Wick China Company, 28
  - Ligonier, 29
- 3. Pittsburgh, 29
  - Star Encaustic Tile Company, 29
  - H. P. Erbe's pottery, 31
- 4. New Brighton and vicinity, 31
  - The clays of New Brighton, 31
  - The potteries, 36
    - Historical, 36
    - New Brighton pottery, 38
    - Sherwood Bros. Co., 39
    - The Enterprise Pottery Company, 40
    - The American Porcelain Company, 40
    - Sewer Pipe and Flue Lining Works, 41
    - The Oak Hill pottery, 43
    - The Beaver Valley pottery, 45
    - The Mayer Pottery Company, 45
    - The Fallston Potter Company, 46
    - The Keystone Pottery Company, 46
    - The Beaver Falls Art Tile Company, 47

Chapter IV. Fire-clays and fire-clay products, general features of, 48
- definition, 48

Chapter IV. Fire-clays, etc.—Continued. Page.
varieties, 50
structure, 50
occurrence, 52
geological position, 53
fire brick, 54
manufacture of fire brick, 57
gas retorts, 60
glass pots, 60
other refractory materials, 62
Chapter V. Fire-clay industries in Western Pennsylvania, 65
1. Ohio Valley, 65
Beaver Valley, 65
Monaca, 67
Vanport, 68
Mahan, 69
2. Pittsburgh, 69
3. Allegheny Valley, 72
Manorville, 73
Cowanshannoc, 72
4. Kiskiminitas—Conemaugh Valley, 73
Salina, 73
Black Lick, 74
Bolivar, 76
Lockport, 86
Johnstown, 87
South Fork, 88
5. Youghiogheny Valley, 88
Layton, 88
Connellsville, 91
Stewarton, 95
Ohio Pyle, 95
Dunbar, 96
Mt. Braddock, 96
Lemont Furnace, 97
White House, 97
6. Monongahela Valley, 98
Courtney, 99
Manown, 100
Chapter VI. Red and buff building brick, 100
Building brick clays, 101
Composition, 101
Physical properties, 102
Varieties, 103
Shales, 104
Classification of building brick, 104
Buff brick, 106
Spotted brick, 107
Vitrified brick for building, 107
Hollow brick, 108
Machinery and methods of manufacture, 108
Methods of handling the clay, 109
Grinding and tempering, 109
Molding, 111

Chapter VI.—Continued. Page.
Repressing, ... 115
Drying, ... 116
Burning, ... 116
Chapter VII. Building brick and paving brick industry in Western Pennsylvania, ... 118
Ohio Valley, ... 118
Vanport, ... 118
Fallston, ... 119
New Brighton, ... 120
Allegheny Valley, ... 121
Freeport, ... 121
Ford City, ... 121
Kittanning, ... 121
Kiskiminitas-Conemaugh Valleys, ... 124
Hyde Park, ... 124
Blairsville, ... 125
Blairsville Intersection, ... 125
Johnstown, ... 125
Between the Conemaugh and Youghiogheny rivers, ... 126
Irwin, ... 126
Rumbaugh, ... 127
Jeannette, ... 127
Latrobe, ... 127
Ligonier, ... 127
Youghiogheny Valley, ... 128
Connellsville, ... 128
Layton, ... 128
West Newton, ... 128
Uniontown, ... 129
Fairchance, ... 129
Monongahela Valley, ... 130
Monongahela City, ... 130
Charleroi, ... 131
Fayette City, ... 131
California, ... 132
Paving brick industry, ... 133
Chapter VIII. The brick works and brick clays and shales of Allegheny county, by W. L. Affelder, ... 134
Introductory, ... 134
Clays and shales, ... 137
Pittsburgh brick yards, ... 140
South Side brick yards, ... 148
Allegheny brick yards, ... 152
Allegheny Valley brick yards, ... 153
Ohio Valley brick yards, ... 155
Monongahela Valley brick yards, ... 157
Youghiogheny Valley brick yards, ... 160
Summary of the brick industry of Allegheny county, ... 161
Chapter IX. Statistics of the clay industry of Western Pennsylvania and analyses of the clays, ... 162
I. List of the potteries in Western Pennsylvania, ... 163
II. List of fire brick works, ... 164
III. List of red and buff building brick works outside of Allegheny county, ... 166

Chapter IX.—Continued.

Page.
IV. List of red building brick works in Allegheny county, 168
V. Statistical summary of the pottery industry, ... 170
VI. Statistical summary of the fire-clay industry, ... 170
VII. Statistical summary of the building brick industry, .. 170
VIII. Statistical summary of clay industries of Western Pennsylvania, ... 171
IX. Statistical summary of clay industries of Pennsylvania for 1896, ... 171
X. Statistical summary of clay industries in United States in 1896, ... 172
XI. Analyses of fire-clays mined in Western Pennsylvania, 173
XII. Analyses of fire-clays and potter clays from different localities, ... 174
XIII. Analyses of pot clays, kaolins and slip clays, ... 175
Index, ... 177

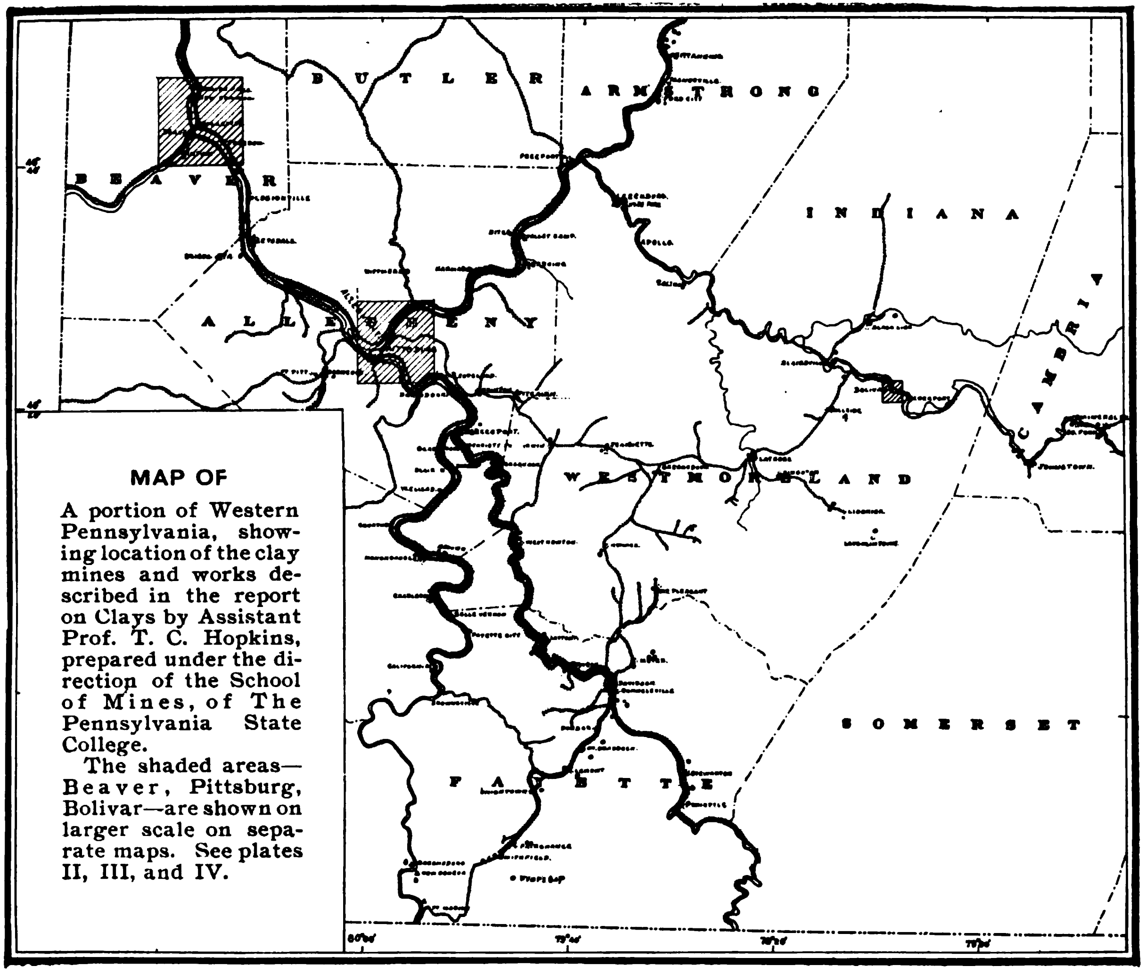
ILLUSTRATIONS.

Figures. Page.
1. Jolly and pull down, 20
2. Jigger department—clay shop—in a china factory, 21
3. Glazing department, in a china factory, 22
4. Gloss kilns, in a china factory, 23
5. Biscuit wareroom, in a china factory, 24
6. View in the printing department, decorating shops, 26
7. View in the filling-in department, in a china factory, 27
8. View of works on the Allegheny Valley Railroad, near Kittanning, 28
9. Pressing department, in a china factory, 29
10. Biscuit kiln, in a china factory, 29
11. Gloss wareroom, in a china factory, 29
12. Vertical sections showing numbers and stratigraphic relations of the clay beds at New Brighton, Pa., 30
13. View of clay mine, New Brighton, Pa., 37
14. Sewer pipe press, 42
15. Jollying flower pots, 44
16. Concentric weathering in flint clay, Bolivar, 51
17. Showing form of flint clay deposits in Missouri, 52
18. Shapes of fire bricks, 55
19. Wet pan for grinding fire-clay, 57
20. Dry pan for grinding fire-clay, 59
21. View of Bolivar, 82
22. Repressing machines at work, Bolivar, 84
23. View of flint clay mine, Moyer, Pa., 92
24. View of flint clay mine, Moyer, Pa., 93
25. Some forms of ornamental brick, 105
26. Horizontal pug mill, 110
27. Martin soft-mud machine, 111
28. Hand cutting stiff-mud machine, 113
29. Automatic wire-cut brick machine at work, 114
30. Steam-power brick pressing machine, 115
31. Drying tunnel, 116
32. Plan of a brick plant, 117
33. Fire clay company's works and mines, 119
34. View of clay manufacturing works and quarry, 122
35. Photo of dry pan in operation, 126
36. View of shale quarry, 132
38. Emptying a kiln, 134
39. Continuous kiln, 135
40. A typical dry floor, 136

Figures. Page.
41. A portion of a brick works, Pittsburg, ... 140
42. Some up-draft kilns, Pittsburg, ... 140
43. Shale and clay quarry, Pittsburg, ... 140
44. Entrance to coal mine, Pittsburg, ... 141
45. Birds'-eye view of terra cotta works, Pittsburg, ... 141
46. Cutting tile, ... 142
47. En route to the kilns, ... 143
48. Setting a kiln, ... 143
49. Views of yard, East End, Pittsburg, ... 145
50. Brick and stone quarry and works, Allegheny county, ... 146
51. Setting a kiln, ... 148
52. A portion of a South Side works, Allegheny county, ... 149
53. A South Side quarry, Allegheny county, ... 150
54. Views of brick yard, ... 151
55. Views in brick yard, ... 155
56. Transporting brick to the railroad cars, ... 155
57. Setting a kiln, ... 155

PLATES.

To face page.
I. Map of Western Pennsylvania, ... 13
II. Map of New Brighton and vicinity, ... 35
III. Map of Bolivar and vicinity, ... 76
IV. King mines, Bolivar, ... 77
V. Indiana mines, Bolivar, ... 78
VI. Map of Pittsburg and Allegheny, ... 136



MAP OF

A portion of Western Pennsylvania, showing location of the clay mines and works described in the report on Clays by Assistant Prof. T. C. Hopkins, prepared under the direction of the School of Mines, of The Pennsylvania State College.

The shaded areas—Beaver, Pittsburg, Bolivar—are shown on larger scale on separate maps. See plates II, III, and IV.

THE CLAYS AND CLAY INDUSTRIES OF WESTERN PENNSYLVANIA.

By T. C. HOPKINS.

CHAPTER I.

GENERAL FEATURES OF CLAYS.

Clay is one of the most useful as well as one of the most abundant substances in nature. Because of certain valuable properties, it adapts itself to a great variety of uses; it is adapted to the simple and urgent needs of the savage and uncivilized tribes as well as to the more complex uses of civilized man. Untutored man finds it suited to his rude culinary needs in forming water vessels and cooking utensils, in constructing his rude dwellings and in making his pipes. As soon as he becomes more civilized and learns letters, he finds that one of the best and most durable means of preserving them is to burn them in clay. Some of the many uses of clay among highly civilized nations are mentioned and described in the following pages.

The scientific definition of clay from a chemical standpoint would be that it is a more or less pure variety of kaolin, the hydrous silicate of alumina. A popular definition would be that it is an earthy substance which becomes plastic when mixed with water.

Composition. –**The base of all clays is the mineral kaolin or kaolinite which consists of alumina, silica, and water combined chemically in the proportion of one of the first to two of each of the second and third, Al^3O^3, $2SiO^2$, $2H^2O$, or in the proportion by weight of silica 46.4, alumina 39.7, and water 13.9. A mineral compound containing only these substances in this ratio is sometimes called pure clay, but pure kaolin might be a better term. Kaolin may generally be recognized by its soapy or unctuous feel, its earthy odor when breathed upon, by giving off water when heated, and turning blue when heated before the blowpipe with cobalt nitrate. In many instances it becomes plastic when mixed with water.**

Kaolin rarely occurs pure in nature. When the impurity or impurities are such as can be wholly or largely removed by a washing or other mechanical process it may still be mined or worked as kaolin. If the foreign substance or substances cannot be so removed, the material is then called clay, with the variety generally designated as brick clay, potter's clay, etc.

Free silica in the form of quartz or sand grains is one of the most common and abundant constituents of clays. Other common impurities are iron oxides, lime, magnesia, titanic acid, and organic matter. Quartz, feldspar, mica, magnetite and limonite are the most common mineral impurities. The relative percentage of these different elements in large measure determines the variety and the use of the clay.

The foreign ingredients are sometimes classed as ((a) non-detrimental impurities and (b) detrimental or fluxing impurities.

But it is questionable whether such a division is a wise one; indeed, it is doubtful if the word impurity is thus used correctly, as what would be detrimental in one clay might be essential in another, so that fluxing and non-fluxing constituents are better terms. The iron, lime, magnesia and alkalies are the fluxing constituents and determine the fusibility of the clay. Of these, the alkalies are the strongest fluxes, but for most uses other than highly refractory ones, iron is the least desirable of the impurities because of the deep color it gives to the clay product.

Of the non-fluxing constituents silica is the most common. Silica occurs in three forms, first chemically combined with alumina in the base of the clay as an essential constituent; second, chemically combined with other bases forming other minerals; third, as free silica, quartz or sand.

The other common non-fluxing constituents are titanic acid, water and carbonaceous material.

Shale is a stratified and a more or less hardened clay and while it may not differ essentially in composition from the unstratified clays, as a rule the shales have a larger percentage of foreign ingredients such as sand and mica scales. Many of the coal measure shales have a strong body yet fuse at high temperatures, thus rendering them valuable for the manufacture of vitrified brick, for which they are used extensively. Many of them are used for red brick and tile.

Origin of clays.—The original source of all the clays is to be sought in the igneous rocks, the decay of which furnishes the material for the sedimentary rocks. The most abundant minerals of the igneous rocks which are rich in alumina or clay material are the feldspars, which are silicates of alumina combined with potassa, soda, or lime. When these minerals are exposed to the disintegrating action of the atmospheric agencies the alkalies are leached out and the more resistant portion, the silicate of alumina, takes up some water into its composition, but still remains insoluble and forms kaolin, the base of the clays. The feldspars and other kaolin-forming minerals are always accompanied by other minerals in the rock forms in which they occur in nature, so that any kaolin which occurs in the position of the original rock from which it was formed, will always be mixed with other mineral substances, such as quartz, magnetite, mica and many others in smaller quantities.

It frequently happens that these impurities are such that they can be separated from the kaolin by water and the stream or flood takes up and carries away as sediment all the decayed rock material and deposits in one place the gravel and heavier materials and in another the kaolin. Where the streams have not done this work in a satisfactory manner man utilizes the same forces and by washing, screening, settling and filtering, separates as far as possible the bulk of the impurities mixed with the kaolin.

As the elements of clay occur in all large bodies of igneous rocks in abundance, the clay materials occur in all soils or disintegrated materials resulting from them. Hence we find clay one of the most abundant and widely distributed substances in nature. But even comparatively pure deposits of the kaolin are few and limited in extent.

Properties of clay.—Clay has three important properties, which render it susceptible to a great many uses, making it almost invaluable to mankind:

First. Its plasticity when wet, by means of which it can be readily fashioned into multifold useful and ornamental forms.

Second. The durability of these forms when burnt, thus cheaply fixing and preserving in durable form the various shapes and designs.

Third. Its ability to withstand high temperatures without injury, thus giving us not only a fire-proof material for our dwellings but a material adapted to metallurgical and heating purposes.

While nearly all clays have these useful properties the different varieties do not have them in the same degree and there is quite a wide range both in the degree of plasticity and the degree of refractoriness, and as a rule the highly plastic clays are not highly refractory. One of the most refractory of clays, the flint fire-clay, is almost entirely devoid of plasticity.

Varieties.—Clays may be classified on several bases, the most common one, however, being that of usage. On this basis clays are classed as potter's clay, including China clay, fire-clay, brick or tile clay and shale. A more extended classification is sometimes used, but the numerous sub-varieties can be conveniently grouped under the three heads.

The following classification is sometimes used, based largely on the chemical and physical properties of the clays:

1. High Grade Clays.—Kaolin, china clay, porcelain clay, ball clay, potter's clay, fire-clay (flint and plastic), glass pot clay.

2. Low Grade Clays.—Brick clay, tile clay, siliceous clay, argillaceous shale, ferruginous shale.

H. M. Wheeler* gives the following classification of the clays.

1. White Ware.—Kaolin, china clay, ball clay.
2. Refractory.—Plastic fire-clay, flint clay, refractory shale.
3. Potter's.—Plastic clay and shale of moderate fusibility.
4. Vitrifying.—Paving brick clay and shale, sewer pipe clay and shale, roofing tile clay and shale.
5. Brick.—Brick clay and shales, terra cotta clay and shale, drain tile clay and shale.
6. Gumbo.—Burnt ballast clay.
7. Slip.—Clays of very easy fusibility.

The character and properties of the different kinds of clays are described in the following chapters.

Uses.—As can well be supposed from its properties, clay has more varied uses than almost any of our natural products. The most common uses of materials made from clay may be enumerated as follows:†

1. Domestic. Utensils, porcelain ware, china ware, granite or stone ware, yellow ware, earthen ware.
2. Structural. Brick, common, front or pressed, ornamental, hollow, vitrified, glazed, enameled, adobe, terra cotta, terra cotta lumber, roofing tile, drain tile, flooring tile, fireplace tile, chimney flues, chimney pots, door knobs, puddling, paving blocks, burnt clay for road metal and for ballast.
3. Agricultural. Drain tile, soil tile, irrigating tile, soil tempering, barn flooring.
4. Hydraulic Structures. Water conduits, reservoir lining, sewer pipe.
5. Sanitary Engineering. Granite ware, urinals, water closet bowls, earthen ware, sewer pipe, absorbent brick, drain tiles, ventilating flues.
6. Industrial Arts. China clay, chemist's crucibles and other apparatus, wall and writing paper filling, refractory clay, lime, cement and pottery kilns, puddling hearths, reverbatory and other smelting furnaces, assaying furnaces, gas retorts, stove and furnace linings, saggars, plugs, models, etc.
7. Ornamental and Aesthetic Uses. Tiling, ornamental pottery, terra cotta decoration, artists' moulding clay, base for retaining pigments.

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*Missouri Geol. Surv., Vol. XI, p. 25.

†From the volume on Mineral Resources of the U. S. for 1891, page 475, published by the U. S. Geol. Survey. A few modern products made since 1891 have been added to the list as given in the Survey report.

8. Imitative Uses. Food adulterant, paint adulterant.

Value.—The total value of the clay products in the United States for 1896 is given[†] at $62,341,853, of which 10.62 per cent. is pottery ware of different kinds, and 89.38 per cent. brick and tile.

The relative rank of Pennsylvania in the clay industries is shown by the following tabulation:

Value of the clay products of the United States for 1896,	$62,341,853
Value of the clay products of Ohio for 1896, first rank,	9,949,571
Value of the clay products of Pennsylvania for 1896, second rank,	9,063,313
Value of the clay products of New York for 1896, third rank,	6,414,206
Value of the pottery ware in Ohio in 1896, first rank, ...	2,899,350
Value of the pottery ware in New Jersey in 1896, second rank,	1,069,142
Value of the pottery ware in Pennsylvania in 1896, third rank,	617,601
Value of fire brick in Pennsylvania, first rank,	2,083,414
Value of fire brick in New Jersey, second rank,	604,983
Value of vitrified paving brick, Ohio, first rank,	619,463
Value of vitrified paving brick, Illinois, second rank,...	486,519
Value of vitrified paving brick, Pennsylvania, third rank,	404,182
Value of pressed and ornamental brick, Pennsylvania, first rank,	662,188
Value of pressed and ornamental brick, New Jersey, second rank,	340,919
Value of common brick, New York, first rank,	4,141,973
Value of common brick, Pennsylvania, second rank, ...	4,118,206
Value of common brick, Massachusetts, third rank, ...	1,601,537
Value of total brick and tile product for 1896, Pennsylvania, first rank,	8,445,712
Value of total brick and tile product for 1896, Ohio, second rank,	7,050,221

From the above it will be seen that Pennsylvania ranks first among the states of the Union in the value of its fire brick, pressed and ornamental brick and in the total brick product. It ranks second in production of common brick and in the total value of all clay products, and third in pottery ware and in vitrified paving brick. This shows not only the high rank of the State of Pennsylvania among the other states in the value of its clay products but also the great value of the clay products in the State as compared with the other resources.

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[*] In the Mineral Resources, 18th Annual Report, U. S. Geol. Survey. See tables I to X, in Chapter IX, of this report for further statistics of the clay industries in Pennsylvania.

Large as the industries are they are capable of much greater extension, especially in paving brick, high grade building brick, ornamental brick, terra cotta ware, tiling and different grades of pottery ware. In the fire brick and common red brick industries the supply is equal to the demand and there is not the same prospect for greatly increasing demand as in the other lines.

CHAPTER II.

POTTERIES AND ALLIED INDUSTRIES.

The pottery ware includes both the highest and the lowest types of the clay workers' skill. It includes the most primitive works of uncivilized man and the highest skill of the most cultivated. There are many centuries of experimenting between the crude bowls and ornaments of the savage and the elegant vases or delicate china ware of the white man. The aggregate value of the product of the potteries is much less than that of the brick product but the price per ton is much higher and varieties in shapes and uses are almost innumerable.

All the pottery industries are commonly divided into four classes, which in a more minute classification might be further separated into numerous sub-classes:

1. Red earthenware.
2. Stoneware.
3. Yellow or Rockingham ware.
4. White ware, including (a) C. C. ware, (b) white granite, (c) semi-porcelain, and (d) porcelain.

The distinctions are based partly on methods of burning and glazing the ware, and partly on the kind of clay used and the care and skill used in preparing it.

1. Earthenware is probably the lowest form of pottery and can be made with proper precautions from almost any of the common yellow clays. It differs from common stoneware in being burned at a lower temperature and in being softer and more porous (more earthy). The only form of earthenware manufactured in Western Pennsylvania at present is red flower pots made at Oak Hill pottery, at New Brighton, and the Erb pottery, Pittsburgh. Drain tile might properly be included in this class, but it is commonly classed with the hollow ware. There is but one factory making drain tile in the part of Pennsylvania covered by this report, viz: Kittanning Clay Manufacturing Co., at Kittanning.

2. Stoneware is probably the largest pottery industry in Western Pennsylvania. There are seven manufactories of stoneware in active operation and several idle ones. Stoneware differs from earthenware in that it is always glazed and the body of the ware at least partly vitrified and it is distinguished from Rockingham or yellow

ware in that the burning and glazing is done in one operation instead of two.

Much of the stoneware is given a brown glaze on the interior by the use of slip clay and a salt glaze on the outside, generally of gray or bluish color, depending upon the character of the clay. Other glazes formed by mixtures of different kinds are sometimes used.

The essential qualities of a good stoneware clay as given by Prof. Orton,* are:

1. It must be plastic so that it can be readily molded into the desired shape.
2. It must be refractory enough to stand up well and keep its shape at a temperature sufficient to melt the glazes.
3. While retaining its shape it ought to undergo a process of vitrification, or probably better lithification, that will not only give it greater strength but render it impervious to water.
4. It should burn with a clear and uniform tint.
5. The ware when burnt should be free from blotches, pimples or blisters.

The average of ten accurate and carefully made analyses of pottery clays in use for stoneware, gives the following result:

Analysis of average stoneware clay.

Clay base,	56.65	per cent.
Sandy matter,	37.45	per cent.
Fluxing matter,	4.44	per cent.
Moisture,	1.57	per cent.
Total silica,	65.00	per cent.

The extremes, however, vary widely from this average and the variation determines largely the character of the clay. Thus all the lighter colored wares demand a clay free from iron or nearly so. Some wares require a clay with a strong body, others require a liberal percentage of fluxes.

The clay is prepared for use either by grinding or by washing. Both processes are used in the Pennsylvania potteries. The grinding is commonly done in a wet pan, somewhat similar to that described on page 55, but it is commonly lighter and geared differently and known as the tracer or chasing mill.

When the clay is washed it is first put into the blunger where it is reduced to a thin slip or fluid pulp, which is transferred to the screens where the pebbles and coarse material are separated. The fine clay and liquid are run then into an agitator from which it is pumped into the filter press. The clay comes from the filter press in flat leaves or plates and is tempered for use in a pug mill.

Turning.—There are three methods of fashioning the ware from the clay: 1. Turning the clay by hand or jigging was the first method used, and until comparatively recent times was the only method. The clay is first wedged by cutting with a wire and kneading, the lump of clay is then slapped on a revolving horizontal disc, which is turned by the foot, "kicking," or by machinery. By pressure of the hand on the revolving mass it is made to take the desired form by the skilled workman. It requires great mechanical skill, that usually comes from long experience, to make an expert turner, a skill in which the workmen take a just pride.

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*Report of the Geol. Sur. of Ohio, Vol. VII, page 92, 1893.

2. A large part of the stoneware, particularly the smaller forms, is now made by a jollying process, in which the clay is placed in the bottom of a plaster-of-Paris cast, the inside of which has the form of the outside of the ware; this is made to revolve on a disc as before. The workman with his hand forces the clay to cover the inside of the cast, then fashions the interior, by a jointed lever, the pull down. See fig. I. When the operation is complete the mold is removed to the drying room, where after partial drying the vessel is removed from the mold, the handles or intricate parts, if any, are put on and it is smoothed and trimmed up ready for the burning kiln. This process is much more rapid than the hand process and is replacing it in large measure in all the larger factories.

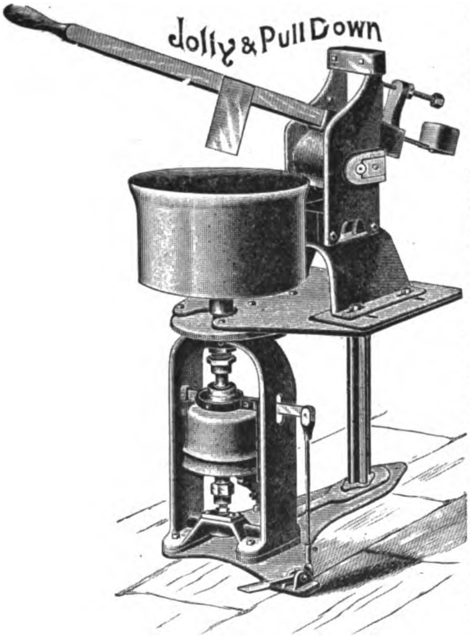

Fig. 1. Jolly and pull down for turning pottery ware.

The third method referred to is casting, in which the clay is reduced to a slip or paste and poured into the mould prepared for it. This is adapted to intricate designs and high grade ware.*

In the potteries in the Monongahela valley the ware is all turned by hand, in the larger potteries at New Brighton the second and third processes are used, although there is some turned by hand in all works, large or small, where miscellaneous material is made.

Glazing.—The next stage in the manufacture of stoneware after the partial air-drying is the glazing, which is usually done with salt or with a more fusible clay called "slip clay." The most common practice is to use a slip glaze on the interior and a salt glaze outside, although in some grades of ware slips are used for the outside as well as the inside. The slip is mixed thin and sprayed over the interior of the ware, which is then ready for the kiln.

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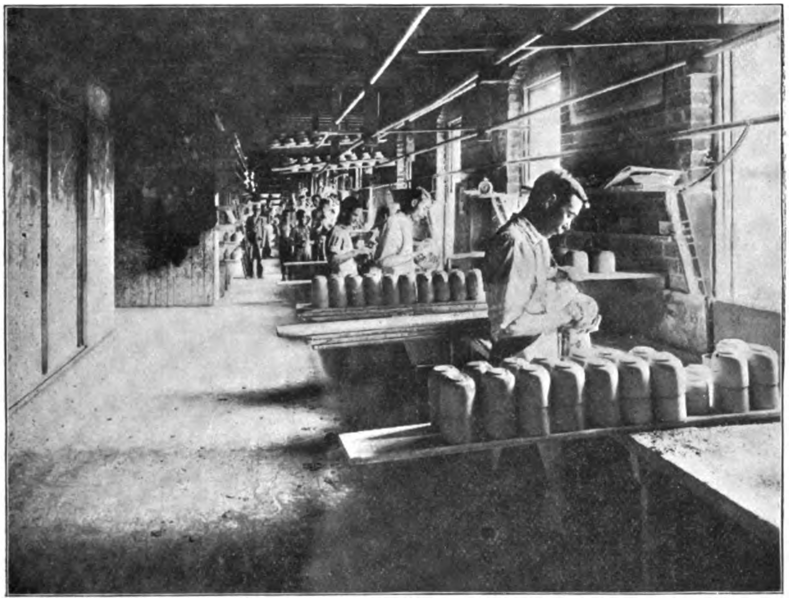
*A new process recently discovered but not extensively used as yet, and applicable only to certain grades of ware, consists in melting the materials and pouring into molds in a fused condition.

The salt glaze is obtained by throwing common salt on the fire at a certain stage in the burning and the fumes of the salt combining with the clay form a glassy silicate coating.

So far as known there is no slip clay obtained in this State. The best known in this country is the Albany slip, from Albany, New York, which is the one used almost exclusively among the potteries in Western Pennsylvania, but some slips imported from foreign countries are used in part in some of the factories. Artificial slips are frequently used by the more skilled potters for certain grades of ware by mixing other substances with the natural slip clays, to vary the grade of fusibility or to give different colors.



Illustrating the processes of making china ware.
Fig. 2. Jigger department—clay shop.

The question of slips and glazes is intimately associated with other classes of pottery, and enameled brick and glazed tiling. It probably calls for more technical skill than any other phase of the industries, especially in the ornamental ware.

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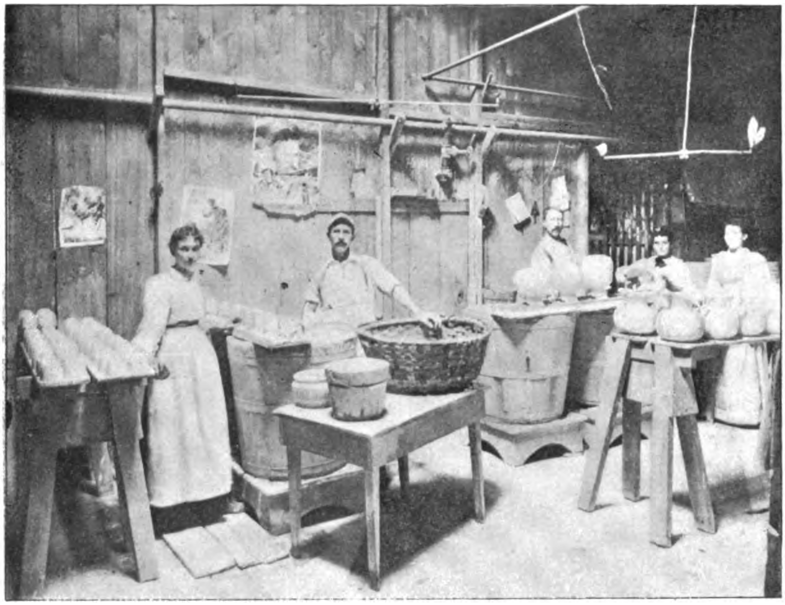
Burning.—The burning of the large ware, as jugs and jars, is conducted in the open kilns by properly stacking or setting the ware and burning similar to brick, regulating the temperature according to the character of the ware and clay. The smaller and more delicate ware is burnt in saggars to protect the ware from the flames. Great care and skill, such as is acquired only by practice, is necessary in setting and burning the ware.

A list of the potteries in western Pennsylvania is given in chapter IX.

Yellow and Rockingham Ware.—Yellow ware differs from stoneware in the manner in which it is burnt. In stoneware the process is completed in one operation. Yellow ware is first burnt in the biscuit kiln to develop the body of the ware and then burnt again to develop the glaze. The same clay may be used for both stoneware and yellow ware, but a less refractory clay may be used for the yellow or Rockingham ware because the glazes fuse at a lower temperature than the stoneware glazes.

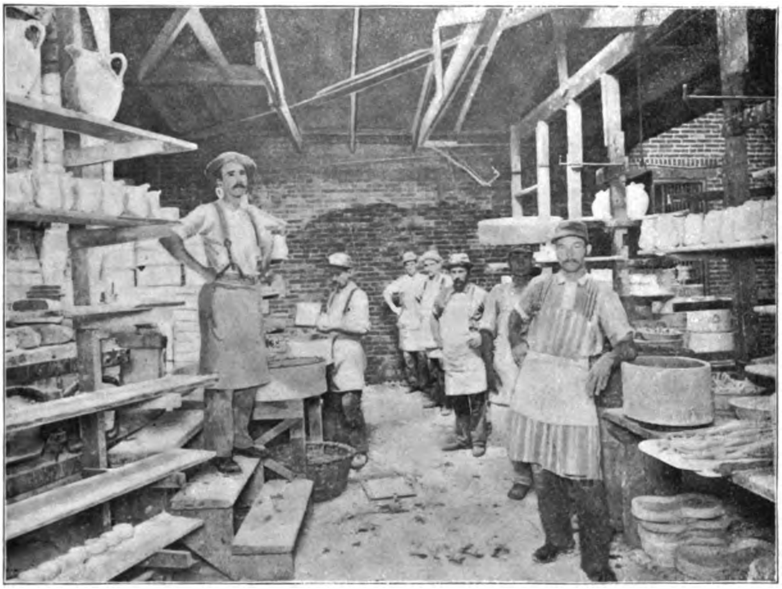


Illustrating the processes of making china ware.
Fig. 3. Glazing department, dipping room.

But little yellow ware is manufactured in western Pennsylvania. The Beaver Valley Porcelain Co., operated at New Brighton for several years, manufacturing washboards and soap dishes of yellow ware, but the company has discontinued. There is a new company starting this year (1897) that, it is said, will manufacture yellow ware in part.

White Ware. —The white ware industry, including the C. C. ware, white granite, semi-porcelain and porcelain, stands at the head of the list of pottery wares in the purity of the clays and skill of the operator required for its successful operation.

The technique of this industry is too varied and complicated to justify a description here. It requires a more costly and expensive equipment, calling for a large capital and more technical knowledge to carry on the industry than the cheaper stoneware, hence there are not so many small operators. There are two large and prosperous white ware factories in western Pennsylvania: The Mayer Pottery Co., located at Beaver Falls, and the Wick China Co., at Kittanning, both described in the following chapter, and the newspapers report another about to start at Ford City.

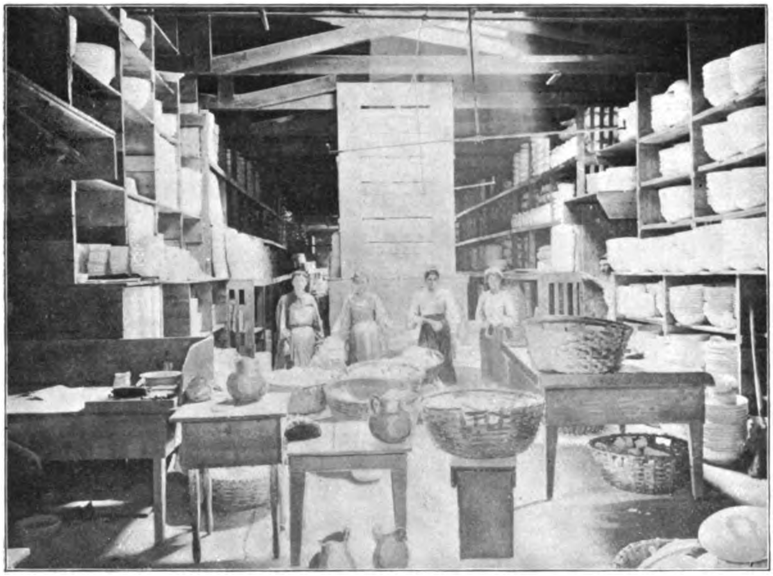


Illustrating the processes of making china ware.
Fig. 4. View at the gloss kilns.

This industry differs from the other grades of pottery ware in the complexity of the mix or material used. Instead of using a natural clay alone, mixtures of clay, kaolin, feldspar and quartz are used, the clay in some cases forming a comparatively small percentage of the total. The body used in china ware by one company is plastic or ball clay (imported) 16 per cent., feldspar 14 per cent., kaolin 35 per cent., flint (quartz) 35 per cent. This of course will vary greatly for different grades of ware and even in the same ware by different companies.

None of these materials is obtained in western Pennsylvania, the only native clay product they use being the clay used in making saggars. The plastic or ball clay is obtained in part from other states and in part from England and Germany. They are now experimenting with a view to using more of the domestic clays.

The kaolin is obtained from Blair, Delaware and Chester counties, Pennsylvania, Florida, North Carolina and Kentucky. The kaolin deposits of Pennsylvania are described in the annual report for 1885 of the second Pennsylvania Geological Survey.



Illustrating the processes of making china ware.
Fig. 5. View in the biscuit wareroom.

Feldspar and flint are obtained from eastern Pennsylvania and other eastern states.

The sewer pipe and flue lining industry is allied in some respects to the brick and tile industry and in some respects to the potteries. There is but one factory of each in western Pennsylvania, those belonging to the Pittsburgh Clay Manufacturing Co., at New Brighton, which are described in the next chapter.

CHAPTER III.

THE POTTERY INDUSTRIES OF WESTERN PENNSYLVANIA.

THE MONONGAHELA VALLEY POTTERIES.

New Geneva, Pa.—The pottery in New Geneva was built in 1854, and was operated for a time by each of the following parties: Mr.

Dilliner, Mr. Everhart and Mr. Atchison. Mr. Dilliner was probably the first, yet the party giving the information was uncertain in regard to the order in which they operated. Mr. A. Conrad was the next proprietor, who sold out in 1882 to R. T. Williams, who operated the works until the present year, 1897. Since April, 1897, they have been operated by C. L. Williams & Co., but the clay deposit still remains in the possession of the R. T. Williams estate.

The clay which they are working at present comes from a river terrace deposit near the top of the river hill, about a mile and a half east of south of the works, on the east side of the Monongahela river. The workable clay is six to eight feet thick, a very plastic blue clay which contains numerous yellow stains near the base and a thin layer of black carbonaceous matter at the top. Closely associated with the black streak is a band of whitish gypsum crystals. Overlying the black streak there is one to two feet of sandy clay overlain by three to five feet of sandy material containing numerous waterworn and angular boulders. The clay is quarried by hand and hauled by wagon to the works at New Geneva.

Clay was formerly obtained in large quantities from a pit about a quarter of a mile west of the present one on the west side of the wagon road and nearer the river than the present working.

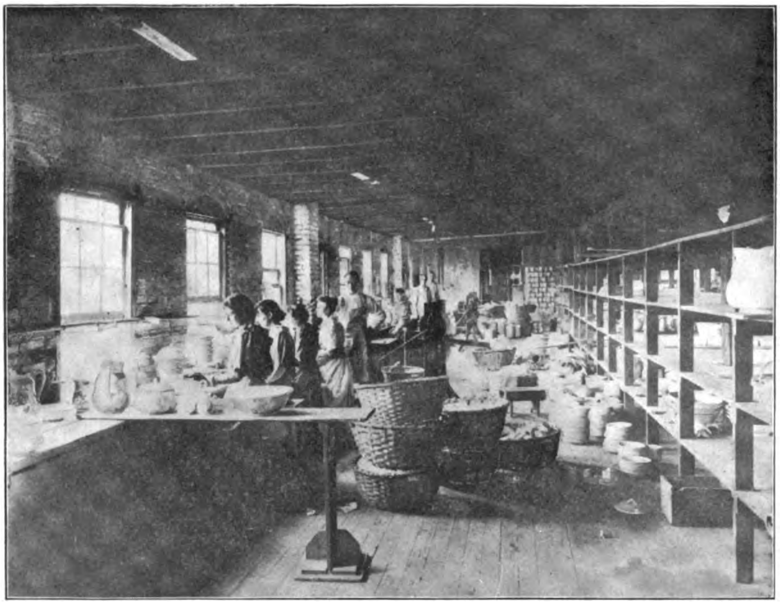
The company makes blue stoneware, such as jugs, jars, etc., with a salt glaze on the outside and a brown glaze formed by the use of the Albany slip clay on the inside. The largest trade is in jugs and Pittsburgh is the chief market, but they have considerable trade in the intervening river towns and points along the Monongahela southwest division of the Pennsylvania Railroad.

They have two kilns and a capacity of 200,000 gallons of ware per year. The ware is all turned by hand and the price is a little higher than that at the New Brighton works, where the ware is nearly all jollied. The large ware is sold by the gallon, and small ware by the dozen.

Both coal and wood are used for fuel. Wood is used for finishing the burning it is said, because it gives more blaze than coal, enabling the burner to finish the ware in better shape.

Greensboro, *Pa.*—Hamilton & Jones constructed a pottery of five kilns on the lower edge of Greensboro in 1866, and operated it from that time until April of the present year (1897), when it was destroyed by fire. Shortly after the fire they rented the pottery on the river bank a short distance below the boat-landing in the village of Greensboro.

This pottery now operated by Hamilton & Jones is said to have been constructed in 1857 or 1858 by W. L. Hamilton, who came from Bridgewater, near New Brighton, abandoning his pottery at that place. No definite information could be obtained as to the length of time Mr. Hamilton operated the pottery or what other parties were in the business. For a number of years previous to 1897 it had been owned and operated by the firm of Williams & Reppert. After the fire had destroyed the works of Hamilton & Jones, Williams & Reppert wishing to go out of the business, rented to Hamilton & Jones their pottery in Greensboro. The pottery is smaller than the one that burned, having but two kilns with a weekly capacity of about 4,300 gallons. Like the New Geneva pottery, they use both wood and coal in burning. It takes 36 to 40 hours to burn a kiln which would be burnt in 24 hours when they used wood alone, as they did a few years ago.

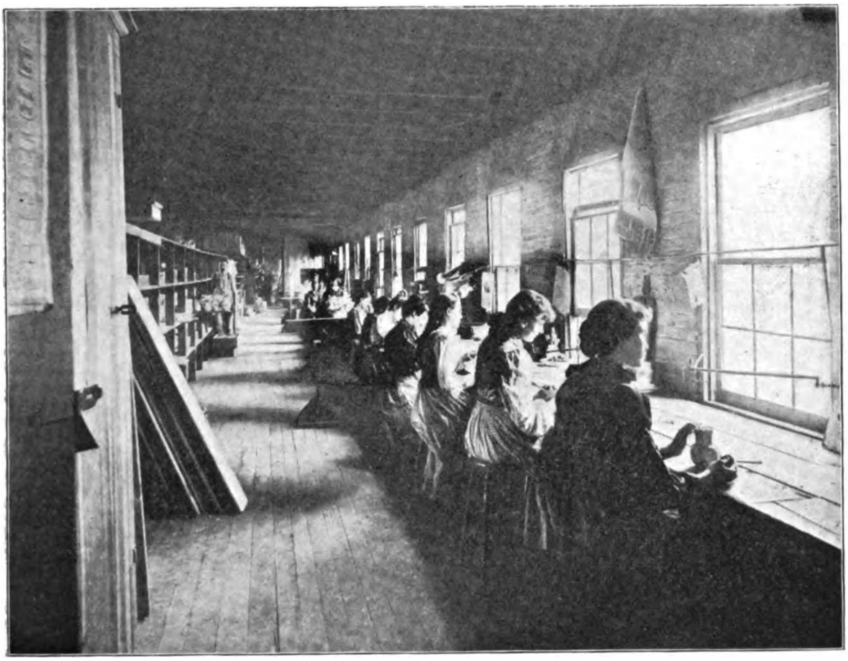


Illustrating the processes of making china ware.
Fig. 6. View in the printing department—decorating shop.

They make jugs, jars, flower pots, etc., but the principal trade is in jugs.

The clay is obtained in part from the R. T. Williams' estate, from the same pit as that from which the clay is obtained for the New Geneva pottery. In part the clay is obtained from their own (Hamilton & Jones) pit, located two miles west of Greensboro, about a quarter of a mile north of the cemetery. The pit has not been worked for some months, and the debris has fallen in, concealing the clay so that neither the quantity nor the quality of it could be observed. It is a terrace deposit like the New Geneva clay as shown by overlying material, which consists of sand and boulders, many of which are waterworn. This clay contains more sand than the Williams' clay and does not make good pottery by itself, but mixed with the Williams' clay it is said by the potters using it to improve the quality of it and make better ware than either clay alone.

Port Marion, Pa.—On the east bank of the Monongahela river, about one mile below Port Marion and about four miles above New Geneva is a small pottery containing one kiln with a capacity of 1,500 gallons per week. It was erected by Dilliner & Dills early in 1896, and operated by them about one year. In July, 1897, it started again under a new company as the Union Pottery Co., consisting of J. E. Eneix, F. L. Cleavenger, J. A. Rumble and A. J. Hayden. They have all had more or less experience and some of them are skilled potters. They do all the work themselves and will no doubt do a successful business. They make the following in blue stoneware: jugs, jars, milk pans, churns and covers, butter jars, preserve jars, fruit jars, pitchers, cuspidors, chambers, beer mugs and bean pots.



Illustrating the processes of making china ware.
Fig. 7. View in the filling-in department—decorating shop.

There is a boat-landing at the pottery, Protson's landing, and most of their ware is shipped by boat. That shipped by rail is hauled to Port Marion, a mile distant, and shipped on the Baltimore and Ohio Railroad.

The clay mine was not visited by the writer. It is said to be about one mile east of the shop and to occur in a bed about four feet thick. Samples of the clay resemble that at New Geneva. As in the other potteries, the Albany slip is used for the inside brown glaze and salt for the outside blue-gray glaze.

2. Kittanning–Ligonier.

Kittanning, Pa.—The Wick China Co., at Kittanning, Pa., claims to be the second largest china factory in the United States. The works are situated close to the tracks of the Allegheny Valley railroad, about half a mile north of Kittanning. They make plain and decorated ironstone chinaware of different kinds and in large quantities. They have eight kilns in use and employ a force of about 350 men, boys and girls.

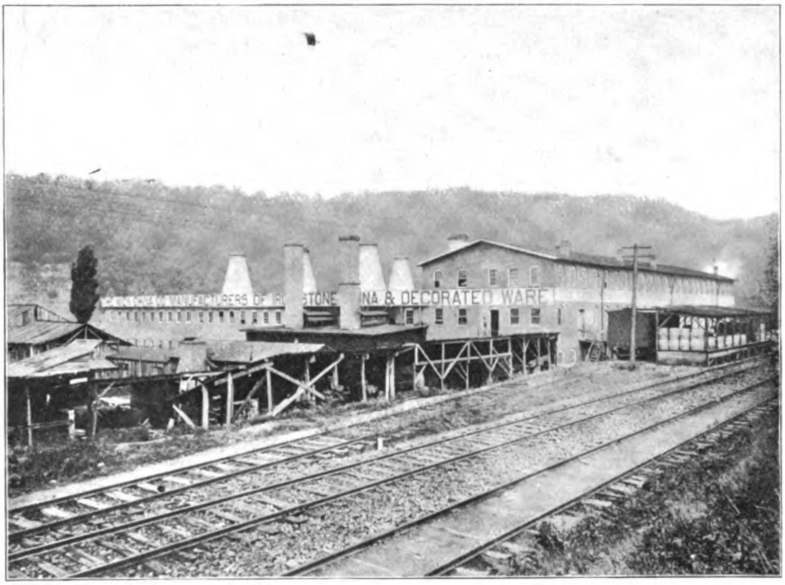


Fig. 8. View of works on the Allegheny Valley railroad near Kittanning.

The bulk of their ware is made from imported clay. They use some kaolin from Brandywine Summit in this State and obtain feldspar and flint from Toughkenamon, Pa. The native clay obtained from the mines of the Kittanning Fire Brick and Clay Co., is used in making the saggars in which the ware is burnt. It is mixed with clay from New Jersey, between 200 and 300 tons of the native clay being used annually.

The works were started in 1890, and have been in active operation

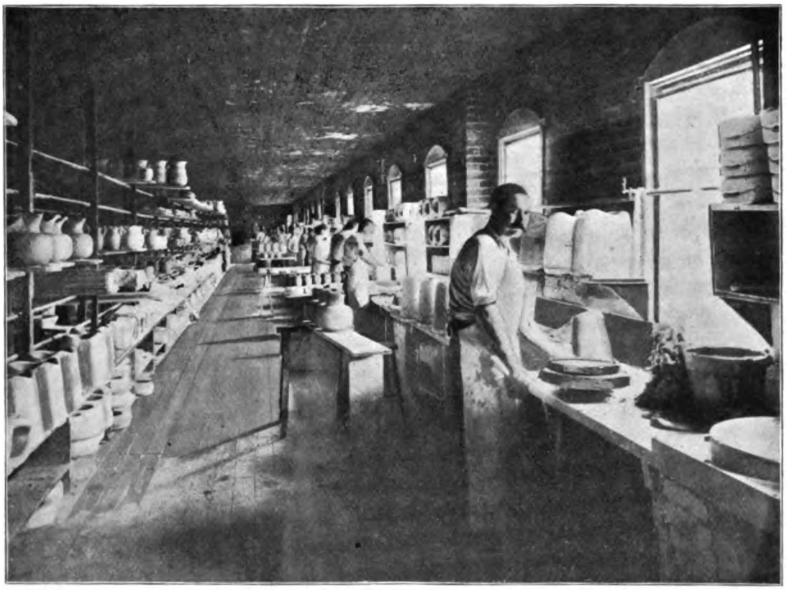


Fig. 9. Pressing department—clay shop.

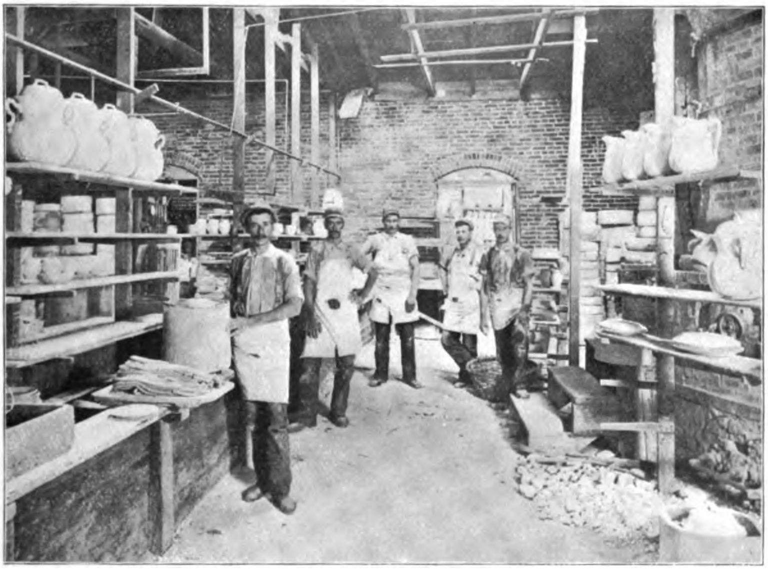


Fig. 10. Biscuit kiln placing.
Illustrating the processes of making china ware.

since that time. The products are shipped to all parts of the United States.

Ligonier.—There was a small pottery in operation for many years at Ligonier, that was started in 1840. The name of the founder could not be ascertained but Mr. John Ware operated it from 1857, until after the war. Mr. Houston Cochran, now living in Cleveland, Ohio, took possession of the works in 1866, and operated them for a number of years. Just when the pottery was abandoned could not be ascertained. The only ware made was crocks, or, as the more modern potter would say, jars. The material used it is said was a blue clay, hauled by wagon from the Denny estate at the old toll gate, about a mile north of Ligonier.

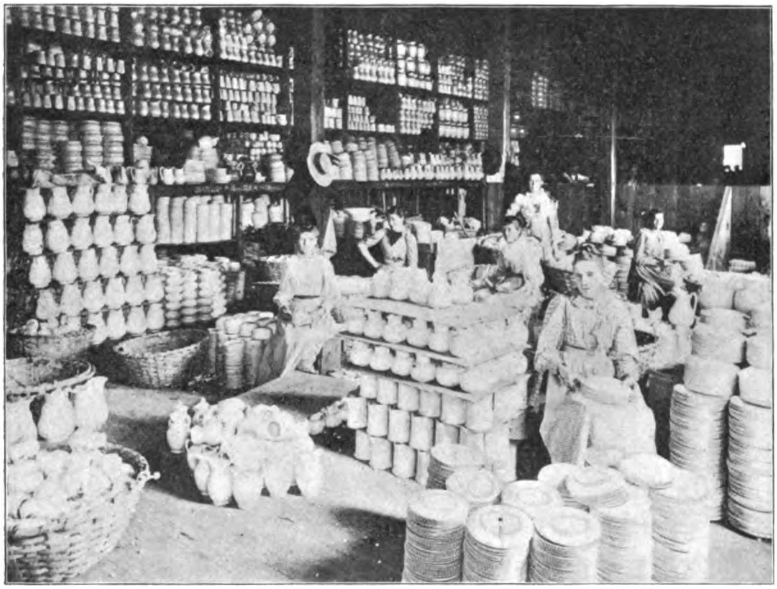


Fig. 11. Gloss wareroom, Kittanning, Pa.

3. PITTSBURG.

The Star Encaustic Tile Company's factory is located in Pittsburgh, Pa., at the corner of Bluff and Gist streets. The business was started in 1876 as the Pittsburgh Encaustic Tile Co., Limited, and was reorganized in 1882 under the present name, and under the present management. The officers of the company are John C. Aldrich, President, Wm. R. Thompson, Secretary and Treasurer, and Samuel Keys, Superintendent. There are several other factories in the United States

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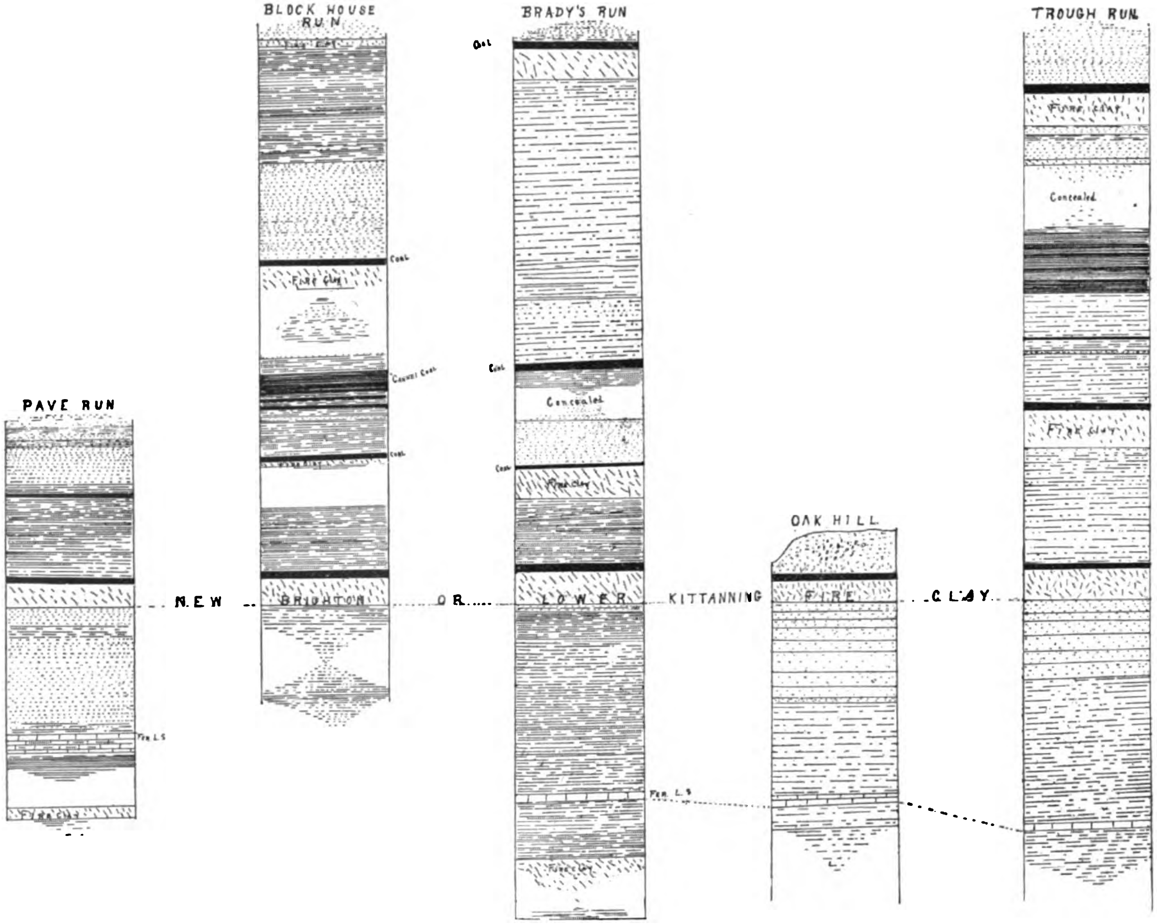

Fig. 12. Series of vertical sections in the immediate vicinity of New Brighton, Pa., showing the relation of the clay beds to the inclosing strata.

making the enameled and glazed tile, three of which also make the unglazed tile, but this company is said to be the only one which confines its operations entirely to making a full line of unglazed tile. They constantly carry a large stock of manufactured goods, and are shipping to all parts of the U. S., and to some extent to Canada. They have also made some shipments to Mexico and South America. The clays used by the company are all domestic, and the two kinds of which the largest quantities are used are obtained, the one near the factory from the Lower Barren Coal Measures, and the other in New Brighton, Beaver county, from the Kittanning bed of the Lower Productive Measures. They use a limited quantity of a clay obtained in the Allegheny mountains, near Hollidaysburg, Pa., and a small quantity of white Florida clay or kaolin. No imported clay is used. The company furnished a handsome tile floor for the space allotted to Pennsylvania in the Mines and Mining Building at the World's Fair, in Chicago, in 1893. The State made this floor and a large lot of samples of tile and clays used by the company formed a part of its exhibit of the mineral resources of the State. Part of this exhibit is now in the museum at State College.

Erb Pottery.—The Erb Pottery is at 26th and Sarah streets, South Side, Pittsburgh. They make red flower pots only and apparently these only on a small scale. No further data could be obtained concerning the works.

4. NEW BRIGHTON AND VICINITY.

The clays.—There are not less than seven different beds of clay in the vicinity of New Brighton. While clay has been used from four different beds, besides some shale from different horizons, the bulk of the clay mined is taken from a single bed, known as the New Brighton or the Lower Kittanning clay, which lies immediately underneath the Lower Kittanning coal.

The accompanying illustration (fig. 12) gives several sections made at different points in this vicinity showing the relations of the clay beds. The lowest bed now exposed at any of the points observed is the Clarion bed, but there is said to be a still lower bed that has been opened near the mouth of Brady's run that is thought to occur at the horizon of Brookville coal and clay, immediately overlying the Homewood sandstone.

The Clarion clay has been mined and used to some extent by the Fallston Pottery Co., on the east side of Brady's run, where it lies in a bed about twelve feet thick at the base of the hill at the pottery works. A drift has been run into the hill about fifty yards and shows the clay to run rather uniform in thickness and character. It was used by the pottery company; but the works are not in operation at present and nothing definite could be learned concerning the results. Some parties interested in other mines say it did not make good ware; other parties say it is better clay than the Kittanning. The Clarion clay is exposed near the mouth of a small ravine on the west side of Brady's run, less than half a mile above the pottery works. There is another exposure in the bottom of Pave run, at the Enterprise Pottery. S. Barnes & Co. state that this clay occurs underneath their works near Rochester, and that they at one time mined a small quantity of it on the river bank opposite their works. It no doubt occurs at many other points in the valley, but has not been opened or developed at any other points. Probably the reason it has not been exploited more thoroughly is that it lies so low that in most places it could be obtained only by shafting, and the Lower Kittanning bed furnishes an excellent clay that can be obtained by drifting.

The Lower Kittanning (Kittanning) clay, is by far the most important bed of clay in the Beaver valley, as it is further down the Ohio valley in the East Liverpool region. It furnishes almost all the clay used in the different potteries and hollow ware works at New Brighton and vicinity, except the ironstone china ware. It also furnishes the greater part of the clay in the large firebrick, paving brick and building brick works in this vicinity.

According to the Ohio state reports it is the Lower Kittanning clay that furnishes the bulk of the product in eastern and southern Ohio, where it is used in even larger quantities than it is in the Beaver valley.

The clay is mined for the Enterprise Pottery Co. by Mr. Emmanuel Evans at the works. Sherwood Bros. mine their own clay at the works. A. F. Smith & Son furnish clay to the porcelain works and in part to some of the other potteries at New Brighton, also to the tile works at Beaver Falls and Pittsburgh, besides shipping clay to many other points. The Pittsburgh Clay Manufacturing Company mine the Lower Kittanning clay for their own use in two shafts near the sewer pipe and flue lining works and in another smaller opening near their Oak Hill pottery. Other points in the vicinity where this clay has been opened and worked are at the works of the Fallston Fire Clay Co., the Fallston Pottery Co., the Brady Run Fire Clay Co., all on
Co., the Fallston Pottery Co., the Brady's Run Fire Clay Co., all on
Dando & Bro. and two works of the Park Fire Clay Co., on Crow's run, near Freedom; Brady's Run Fire Clay Co., and Welch, Gloninger & Co., at Monaca; the Vanport Fire Clay Co., and Welch, Gloninger & Co., at Vanport; the Park Fire Clay Co. below Vanport; the Stahl Fire Brick Co. below Beaver on the south side of the Ohio river. It was formerly worked by L. S. McKallip & Co., on the south

side of the Ohio river, opposite Beaver and by the Keystone Pottery Co. at Rochester. Mr. White and Mr. Fish have both opened this clay on their property at Bennetts run above New Brighton on the east side of the Beaver river. Mr. White has mined the coal and taken out some of the clay with the coal. Mr. Fish has been taking the coal from above the clay and the flagstone underneath the clay but has made no use of the clay as yet.

The clay forms a continuous bed throughout this region and will no doubt be opened at other points in the course of time. The clay bed is probably continuous from the Beaver valley region to East Liverpool, Ohio, where it is used so extensively. The writer did not have the opportunity to explore the region west of the Vanport dam, but was informed by local geologists that the conditions are not favorable for working the clay, as it is concealed under a heavy drift or river terrace deposit and it is said that the clay is not utilized at all in this intervening region, that is, between the Vanport works and those in Ohio.

The clay runs rather uniform in thickness throughout the Beaver valley region, but the thickness mined at the different works varies. This is partly due to the fact that the bed varies in thickness and partly to the fact that the lower part of the bed grades almost imperceptibly in places from the smooth plastic clay into a flaggy sandstone. The brick works can use more of the sand than the potteries and some grades of the pottery ware can stand more than other grades. The upper part of the bed is rémarkably even, the coal bed overlying it preserving an almost uniform thickness of 22 inches throughout the area (see fig. 12), but there are occasional rolls in the bottom of the clay bed extending in places two feet or more into the bed. The thickness of the clay mined thus varies from four to nine feet at different points, averaging about six feet, one company claiming a thickness of sixteen feet, which presumably includes considerable of the underlying sandstone. The thickness worked by some of the leading companies at their mines is as follows:

Sherwood Bros, seven feet.
Enterprise Pottery Co. eight feet.
Sewer Pipe Works six to seven feet.
A. F. Smith & Son six to seven feet.
Ingram & Co. seven to eight feet.
Welch, Gloninger & Co., Monaca, six feet.
Brady's Run Fire Brick Co., Monaca, sixteen (?) feet.
Brady's Run Fire Brick Co., Monaca, sixteen feet.
Stahl Fire Brick Co. six feet.

The clay shows no evidence of lamination except in the sandy layers at the base. It comes from the mines in moderately hard, irregular lumps, which on exposure to the weather quickly crumble into fragments and later into soft, plastic clay. Most of the companies keep a large stock of clay on hand so that it can be exposed to the weather several months before using it, as it works so much better than the fresh clay, which is seldom used except in case of necessity. The clay is ground in a dry pan and screened before using and in the potteries and tile works it is washed and screened.

This bed of clay has been a great source of wealth in the Beaver valley and vicinity and no doubt will continue so for many years to come.

The commercial importance of the Lower Kittanning clay in Ohio is shown by the following extract from the Ohio state report.*

"Under this head we come to the great clay horizon of the state. Its importance far outweighs that of any other clay seam of our scale. Indeed, it is probably equal in value, to all other sources of clay in the Coal Measures combined. In its more important fields it ranges in thickness between eight and thirty feet. In some districts it is merged, with only the interruption of the Lower Kittanning coal seam, into the clays that belong next in the ascending series, viz: those which come in below the middle Kittanning coal. In this case the combined deposits constitute a section measuring not less than fifty feet. The Kittanning clay horizon proper is seen at its best where it enters the state from Pennsylvania, and again where it leaves the state in its extension into Kentucky.

"As a rule, the horizon produces a white plastic clay, almost always of fair quality and, in places, of the highest excellence. The plastic clay is the foundation of the great pottery industries of eastern Ohio, where it is worked on a very large scale. A second, and even more valuable phase of the clay is found at a few points in Stark, Tuscarawas and Carroll counties. The formation here yields a hard or flint fire-clay of quality scarcely inferior to the best clays of the country. This phase is known under the name of the Mineral Point clay. It is largely worked and manufactured at the village of this name, and at Canal Dover, as well, and the products have an excellent name in all markets, for their refractory quality.

"Analyses of the Mineral Point clay have been often published. A single one will be quoted here, fairly representing the formation (Lord). The figures show a clay of great excellence:

"Combined silica,	35.39 per cent.
"Alumina,	31.84 per cent.
"Combined water,	11.68 per cent.
"Percentage kaolinite base,	78.91 per cent.
"Free silica,	17.13 per cent.
"Titanic acid,	1.68 per cent.

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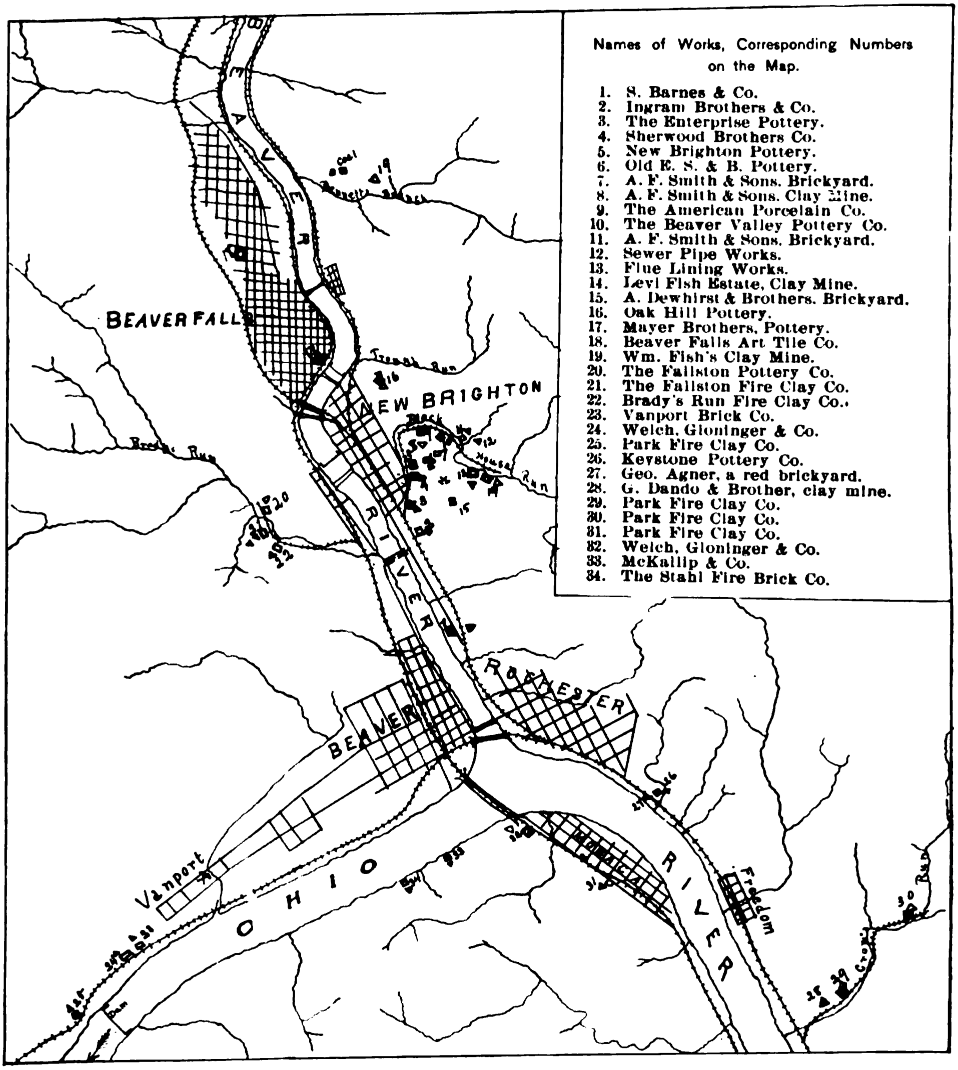
*Ohio State Geol. Survey Report, Vol. VII, p. 65.

PLATE II.



Names of Works, Corresponding Numbers on the Map.

1. S. Barnes & Co.
2. Ingram Brothers & Co.
3. The Enterprise Pottery.
4. Sherwood Brothers Co.
5. New Brighton Pottery.
6. Old E. S. & B. Pottery.
7. A. F. Smith & Sons. Brickyard.
8. A. F. Smith & Sons. Clay Mine.
9. The American Porcelain Co.
10. The Beaver Valley Pottery Co.
11. A. F. Smith & Sons. Brickyard.
12. Sewer Pipe Works.
13. Flue Lining Works.
14. Levi Fish Estate, Clay Mine.
15. A. Dewhirst & Brothers. Brickyard.
16. Oak Hill Pottery.
17. Mayer Brothers, Pottery.
18. Beaver Falls Art Tile Co.
19. Wm. Fish's Clay Mine.
20. The Fallston Pottery Co.
21. The Fallston Fire Clay Co.
22. Brady's Run Fire Clay Co.
23. Vanport Brick Co.
24. Welch, Gloninger & Co.
25. Park Fire Clay Co.
26. Keystone Pottery Co.
27. Geo. Agner, a red brickyard.
28. G. Dando & Brother, clay mine.
29. Park Fire Clay Co.
30. Park Fire Clay Co.
31. Park Fire Clay Co.
32. Welch, Gloninger & Co.
33. McKallip & Co.
34. The Stahl Fire Brick Co.

MAP OF NEW BRIGHTON AND VICINITY

Showing location of Clay Mines and Works. Prepared under the direction of the School of Mines of The Pennsylvania State College, by Assistant Prof. T. C. Hopkins. Base of the map adapted from map of Beaver County compiled by H. T. Barker.

"Sandy material (total), ...	18.81 per cent.
"Sesquioxide of iron, ...	0.67 per cent.
"Lime, ...	0.50 per cent.
"Magnesia, ...	0.19 per cent.
"Potash, ...	0.59 per cent.

"Of the ordinary phase of the deposit, viz: the white plastic variety, abundant analyses are at hand, but it is hard to find any one that can be called thoroughly representative. In the discussion of clays in manufactures in a succeeding chapter, numerous analyses will be found. The products of this horizon are used on a great scale in the finer pottery manufacture for saggars, also in part for the manufacture of Rockingham and yellow ware; and, lower still in the scale of value, for stoneware. These clays are a main dependence of great sewer pipe factories, and also are sometimes used in making fire brick of ordinary quality. An enormous amount is now being turned to account in the manufacture of paving brick. By reason of the uses and adaptations above named, the Kittanning clay seems certain to hold for all time to come the first place in our clay horizons."

Middle and Upper Kittanning clays.—Clay occurs in the Beaver valley in several localities at horizons above the Lower Kittanning supposed to correspond to the horizons of the Middle and Upper Kittanning coal, but so far as known to the writer they have not been utilized in this region. Their relative positions are shown in the sections on figure 12.

Lower Freeport clay.—A bed of clay supposed to be at the horizon of the Lower Freeport occurs at several places and has been mined to considerable extent in one locality by the Fallston Fire Clay Co. They use it to mix with Lower Kittanning clay in different proportions to get different grades of brick. In several places the outcrop of this clay shows a very plastic light colored clay of great promise, but in most places it contains scattered fragments of iron oxide that stain it more or less. It is questionable how much of the iron could be removed by washing. If it could all be removed economically the clay would make a good plastic clay. If it could not be removed it might still be a valuable clay for brick making.

At the sewer pipe works, the Pittsburgh Clay Manufacturing Co. has mined a clay bed at a still higher horizon, which was not seen by the writer but which Mr. Brown, the superintendent, thinks belongs to the Mahoning horizon. They do not use it at present and have not for several years.

Terrace clay.—At the Oak Hill pottery the Pittsburgh Clay Manufacturing Co. use a clay from the river terrace deposit at the works. They mix it in certain proportions with the Lower Kittanning clay mined at the same place. It contains more iron than the Kittanning clay and gives the red color to the flower pots made of it. The Terrace clays have been used at several other points on the east side of New Brighton for making red brick and it was used at one time by Elverson & Sherwood, on Block House run, for making red flower pots.

*Analysis of terrace clay at New Brighton, Elverson & Sherwood:**

	Per Cent.
Silica (SiO^2),	67.780
Alumina ($Al^2 O^3$),	16.290
Titanic acid (TiO^2),	.780
Iron oxide (Fe^2O^3),	4.570
Lime (CaO),	.600
Magnesia (MgO),	.727
Alkalies,	2.001
Water,	6.340
Total,	99.088

POTTERIES AT NEW BRIGHTON AND VICINITY.

The pottery industry at New Brighton and vicinity is a very important one. There are three large stoneware factories in active operation in New Brighton, and one now idle at Fallston, near by, a large white ware or stone china ware factory at Beaver Falls, a flower pot factory, a hollow ware factory, a sewer pipe works, a flue lining works, all in active operation at New Brighton, a washboard factory now idle, and a small pottery just starting, an art tile factory at Beaver Falls and large quantities of clay shipped in a raw state to distant points. It will thus be seen that there are nine large factories in active operation and two idle at present, all of which use the native clay more or less, one only in small part but most of them almost entirely.

Historical.—The first attempt at pottery-making in the Beaver valley, so far as can be ascertained, was about the year 1834, when Thomas Jackson started a small pottery at New Brighton. The panic of 1837, so disastrous to the business interests of the country caused suspension of business by Mr. Jackson.

Possibly the next venture was by the Hamilton Brothers, Lute and James, at West Bridgewater. The date when they began operations is not known to the writer, but Mr. Dicky, now 70 years of age, says that the Hamilton Brothers were making pottery in Bridgewater longer ago than he can remember. While he has no recollection of when they began, he feels certain that it was fully fifty years ago that they ceased operations and removed to Greensboro, Greene county. (About 1857-8, see p. 25.) The Hamilton Brothers obtained their clay on the hill near Mr. Dicky's house on the west side of Brady's run, near its confluence with the Beaver river. They made common stoneware, the chief trade being in crocks and jugs. They would ship by boat to points along the Ohio and Mississippi rivers. The reason for their removal to Greensboro is not known.

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*Second Geol. Surv. of Pa. Report, MM. p. 257.

Mr. Dicky states that to the best of his knowledge the first clay mined in the Beaver valley was used by the Mackenzie Bros. at Vanport, in a pottery at that place. No definite information could be obtained concerning the pottery industry at Vanport, except that it began at an early date and was continued by the Mackenzies and the Fowlers until quite recently, stopping only a few years ago.

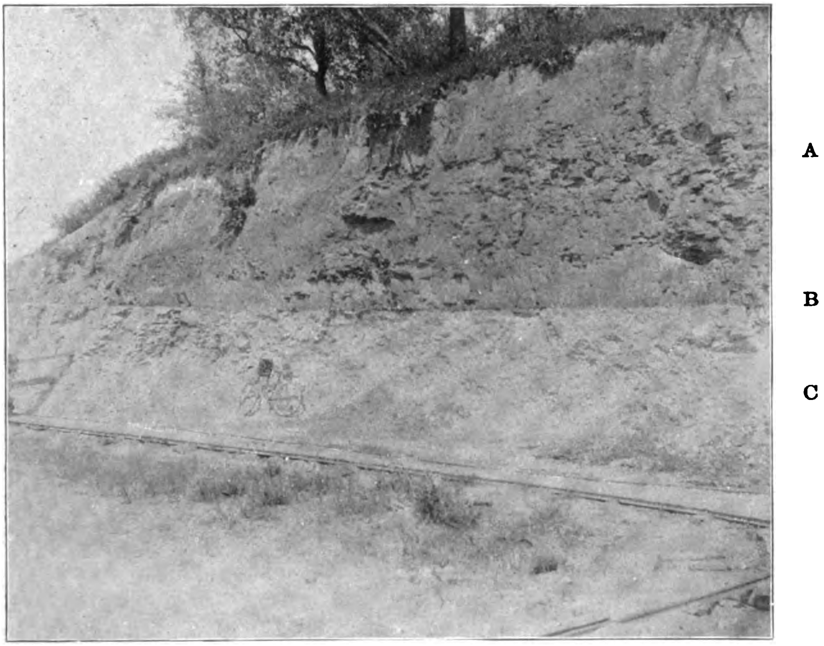

Fig. 13. View showing face of clay, coal and overlying shale in clay mine at New Brighton, Pa. A—shale; B—Kittanning coal; C—Kittanning fire-clay 7 feet.

Mr. A. F. Smith, of New Brighton, his son and his father, now deceased, have been closely connected with the clay industry in the Block House run region for many years. They were early settlers in this region, and realizing the possibilities in this great bed of potter's clay, they bought up much of the land in that region and for many years they have been mining clay and shipping it to different points in the United States and Canada, besides furnishing some of the home works.

The beginning of the present large pottery and kindred industries at New Brighton was in 1862, when Mr. Thomas Elverson, through the inducements offered by Mr. Smith, began making Rockingham and yellow ware in the little pottery on the hillside above the present site of the New Brighton pottery works. This little pottery, which is the mother of all the large works now in the valley, is owned by Mr. Smith, and has been idle for a number of years, but is now (1897) starting again on a small scale.

Mr. Elverson subsequently admitted Mr. H. A. Fisher as a partner, the firm being changed to Elverson & Fisher. Mr. Fisher later sold his interest to Mr. W. H. Elverson, son of Thomas Elverson, and the firm name was changed to Elverson & Son. In the year 1869 Mr. John Sherwood purchased an interest in the firm, the title of which was changed to T. Elverson, Son & Co., and the flower pot industry was added. Subsequently Mr. T. Elverson withdrew and the firm name was changed to Elverson and Sherwood, and thus continued until 1879, when Mr. C. A. Barker purchased an interest, when the title was again changed to Elverson, Sherwood & Co., and the large works now known as the New Brighton pottery was constructed, but they continued to operate the small works on the hill several years longer. In 1881 Mr. Louis H. Barker became a partner and the firm was changed to Elverson, Sherwood & Barker. In 1885 the firm organized under the limited partnership act and became Elverson, Sherwood & Barker, Limited, and so remained until 1890, when it merged into the Pittsburgh Clay Manufacturing Co., the company now operating the works.

In 1877 G. W. and W. D. Sherwood started a large pottery on Block House run, a short distance below the above, under the name of Sherwood Bros. Co. Both the above brothers are now deceased and for five years the business has been under the management of Mr. John Sherwood, still retaining the same firm name.

The Enterprise Pottery Co. was established, it is said, sixteen years ago, but has been under the management of the present company since December, 1893.

New Brighton Pottery Works.—The New Brighton pottery, as already stated, is the outgrowth of the small pottery started by Mr. Elverson in 1862. It is now owned and operated by the Pittsburgh Clay Manufacturing Co., who also own and control the sewer pipe works, the flue lining and flower pot works described elsewhere. The present officers are Mr. W. F. Lloyd, president; Mr. J. P. Sherwood, vice president; Mr. C. A. Barker, treasurer; T. D. Brown, secretary and superintendent of pipe works; Mr. W. H. Elverson, superintendent of potteries. They have nine kilns and a capacity of about 1,800,000 gallons per year, and employ a working force of about 125 men and boys. A side track from the Pittsburgh, Fort Wayne and Chicago Railroad runs to the works, and they are equipped for manufacturing and shipping all grades of stoneware and glazed ware. Their illustrated catalogue shows the following ware of many sizes: Butter pots, open jars, cream or Dutch pots, churns, jars and lids, water coolers, jugs, counter box, bottles, milk pans, bean pots, jelly cups, mugs, chambers, pitchers, cuspidors, fruit jars, chicken fountain, natural gas burners, and feed troughs.

They mine their own clay in part and purchase part of it from A. F. Smith & Son, using the native clay for the manufacture of all their ware. They use the Albany slip glaze and some New Jersey clay to mix with the native clay for the saggars.

Sherwood Brothers Co.—The works of the Sherwood Brothers Co. were started in 1878-79, by G. W. and W. D. Sherwood, who started with one kiln and one small building, but have enlarged their facilities from time to time until they are now well equipped in every way for manufacturing and shipping stoneware on a large scale. This company, now managed by John P. Sherwood, claims to be the most progressive one in the valley in getting out new inventions and making high grade ware. They originated the fine glazed milk pan and are the inventors of the glazed stew pan so well known throughout the country, the self-sealing fruit jar, that has had such a large sale, and shipping pail. They claim also to be the only firm in this country that makes the genuine light glazed Bristol ware, also the only company in this country that makes the stone screw-top jug for holding acids and other chemicals.

The fact that this was the only company from this region that had an exhibit at the World's Fair in 1893 is an indication of their progressive character. They now have eight kilns, two decorating kilns, and have a capacity of fifteen tons of clay per day, and employ a force of 125 men and boys.

They make the following, as shown in their illustrated catalogue: Jugs common bailed, mustard and screw top, ammonia jar, cremation jar, bottles of many sizes and shapes, beer mugs, jelly jars, packing jars, preserve jars, fruit jars, butter jars, snuff jars, cheese jar, beef extract jar, cosmetic jar, bean pot, shipping pail, coffee and tea pots plain and decorated, cuspidors plain and decorated, stew pans, milk pans, chair pans, mixing bowls, individual bakers, and water filters. Beside the above they make numerous fancy and decorated articles not shown in their catalogue.

The works are on a side track from the Pittsburgh, Fort Wayne and Chicago Railroad, and the wares are shipped in large quantities to all parts of this country. They have an extensive trade in New England, and other eastern markets. They obtain their clay from the Lower

Kittanning bed on the hillside at the works, and use a thickness of about six feet of the bed. Unlike many of the other clay works in the Beaver valley, this company owns its own clay land.

The Enterprise Pottery Co.—The Enterprise pottery is about 300 yards south of that of the Sherwood Bros. Co., on the side track from the Pittsburgh, Fort Wayne and Chicago Railroad, and the one nearest the mouth of Block House run. It was established about sixteen years ago and has been operated by the present company since December, 1893. They have three kilns and an annual capacity of about 800,000 gallons, with a working force of about 40 men and boys.

They make a variety of stoneware all of which is dark glazed on the inside. Their illustrated catalogue announces the following wares: Butter pots, tie jars, water jars, preserve jars, fruit jars, churns, bean pots, cream or Dutch pots, jugs, stew pans, milk pans, mixing bowl, jelly cups, pudding bowls, pipkins, shipping pails, bailed pails, chicken fountains, chambers, match holder, knife sharpener, mugs, cuspidors, water pitchers, water filters, greenhouse and window pots.

Their clay, which comes from the Lower Kittanning horizon, is mined by contract on the hill near the works. They pay so much per ton for it delivered on the dump.

The American Porcelain Co.—The works of the American Porcelain Co., are located on Block House run, at New Brighton, Pa. They began operations about three years ago and much of the time since then has been spent in experimenting. They at present appear to be in condition for doing a good business. They now claim to have a porcelain that will not craze or crack, moreover it is put on the green clay and all burnt at one firing, which is a saving over the biscuit burning method.

They now manufacture bathtubs, sinks, laundry tubs and refrigerator linings. They are pioneers in much of this work. The refrigerator lining they began last year and this year they say the output will be doubled. They all go to the Monroe Refrigerator Co., Lockland, O. The possibilities in this line are great, as the porcelain lining is certainly an improvement over the zinc in cleanliness, neatness and healthfulness. It needs but a glance at the interior of one of these porcelain lined refrigerators to show its desirability. The company makes three grades of these goods, one in which the porcelain is confined wholly to the interior of the vessel, another in which the porcelain extends out over a rounding rim, another which is porcelain inside and out. The last is the most expensive, the first the cheapest. The ware is made in plaster-of-Paris mold, partially dried in the molds, then air dried and burnt in saggars in kilns. Great care is necessary in drying the large pieces and still greater care and skill are required in the burning and cooling or annealing operations.

The objections to bath tubs of this kind are their greater weight, which is from 500 to 700 pounds, and greater cost. These objections apply in a less degree to the sinks and laundry tubs. Yet they are so much neater and cleaner that for the better class of buildings they will be in demand despite their greater cost. The greater weight is not a serious objection as they are stationary objects.

The company states that their best markets are New York and Boston, where more expensive buildings are constructed. While they sell in Pittsburgh, Chicago, Cincinnati, St. Louis and elsewhere, the bulk of their trade is in the east as the more western cities demand a cheaper ware.

They have no rivals in this State and very few in this country. The company states that while there are three or four firms in the United States that manufacture a somewhat similar ware, with one exception the others make a cheaper grade of ware and hardly come into competition.

T. E. Marshall is the president and general manager; W. A. P. Graham, secretary and treasurer.

Sewer Pipe Works of the Pittsburgh Clay Manufacturing Company. --The sewer pipe works are about a mile above New Brighton on the east side of Block House Run on the side track from the P., F. W. & C. R. R. The works were started August 1, 1887, by the Pittsburgh Sewer Pipe Co., Limited, which changed its title in 1889 to the Pittsburg Sewer Pipe and Fire Clay Co., and in 1890 consolidated with the Elverson, Sherwood and Barker Co. into the Pittsburgh Clay Manufacturing Co. Mr. T. D. Brown superintends the sewer pipe works.

The sewer pipes are made from the New Brighton or Lower Kittanning clay, the same bed that is worked at the potteries and not differing greatly in quality from that in the other mines. It is six to seven feet thick and overlain by twenty to twenty-two inches of coal. The company opened the Upper Kittanning clay but did not use it to any extent as it was too impure.

They also opened a bed of clay at a higher level, said to be twelve to fourteen feet thick, which they used during the period from 1889 to 1893 for making paving brick, of which they made a great many. In 1893 they ceased making paving brick, claiming that the price was too low for profit.

They mine their clay through shafts, the upper one in the valley being 45 feet deep. The strata dip southeast into the hill, thus necessitating pumping the water from the mines

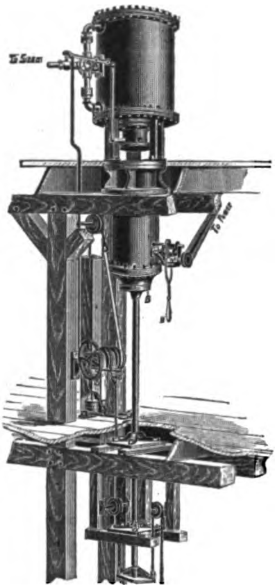

Fig. 14. Sewer pipe press.

The sewer pipes are made by machinery. (See fig. 14.) The clay is first finely ground in drypans and screened, then thoroughly mixed, and tempered and fed into the vertical clay cylinders, where the piston or plunger is slowly forced down on the clay, pressing it through the die at the bottom, where it is cut off in the desired lengths and then removed to the drying floor, where they are air-dried for six to ten days, which process requires considerable care to prevent cracking. They are burned in kilns from five to six days and allowed about the same time for cooling. Great care is necessary in the cooling or annealing process as a touch of cold air before they are cooled sufficiently will crack and thus spoil them. They are all salt glazed, which renders them impervious to water. They are all burned to a reddish-brown color. The clay used for the sewer pipe differs but little from that used in the potteries and could be used for a light colored pipe, but Mr. Brown, the manager, says the market demands a brown pipe, and there is no sale for a light colored one, even though it might be equally good or better than the brown colored. The supposed reason for this whim is that the first pipe made in this country was brown; it was good; therefore only brown sewer pipe is good sewer pipe.

Pipes of 6-inch, 8-inch and 12-inch diameter are the more common sizes, but a great many other sizes are made and kept in their large stock. The storage yard covers an area of several acres. Their markets are mostly eastward to eastern Pennsylvania and the New England states, much of it going to Massachusetts.

The flue-lining factory is alongside of the sewer pipe works, immediately adjoining it on the east side, and belongs to the same company, viz: the Pittsburgh Clay Manufacturing Co. They manufacture flue linings, fire-clay pipe and fittings, bonnets, chimney tops of different styles, Mandary tops, wind guard tops and fire brick. They do not solicit fire brick orders, but handle the fire brick to fill small orders along with their other products. Their principal trade is in flue linings, for which they have fitted their works and which receives their chief attention and efforts.

The flue linings are made somewhat like the sewer pipe out of the ame kind of clay. The clay is ground, screened, mixed and then fed into a machine similar to the sewer pipe press. The pieces are then dried and burned, but are not salt glazed like the sewer pipe and are not colored, but have a light buff or cream color. They are made in sections about the same length as sewer pipe, and are of different shapes, but the most common form has a rectangular cross section with the corners rounded especially on the inside. These are placed one on top of another the desired height of the flue and a row of bricks built around them. They have the appearance from the outside of a common brick chimney, but give a larger inside space in proportion to the outside than the common flue. It is also smoother, the inside having fewer projections to catch the soot; it is at the same time safer, as there is less possibility of flames or sparks getting through them than through the common brick chimney. The company has a large sale for the flue linings and like the other works in the valley find their largest markets east. The economic advantages of these flue linings are so great that there will certainly be a large home market for them in the course of time as they become better known.

The Oak Hill Pottery, Pittsburgh Clay Manufacturing Co.—The Oak Hill Pottery is situated on the top of the hill overlooking Beaver river, opposite Beaver Falls and a mile and a half north of the village of New Brighton. The works were constructed and first operated by D. G. Schofield & Co., manufacturers of greenhouse flower pots and miners of fire-clay, a number of years ago, but the exact date of starting could not be ascertained. They failed about four years ago, and the works lay idle one year; one year they were in the hands of a receiver, and were then purchased by the Pittsburgh Clay Manufacturing Co. Mr. J. M. Lourimore is now manager of the works.

They make only red flower pots for greenhouses and window seats, and have a capacity of about 20,000 pots per day. Clay is obtained from the Lower Kittanning bed, on the east side of the works and mixed with a yellowish clay from the terrace deposit obtained at the northwest corner of the works. The latter, which is used in larger proportions than the light clay gives it the red color after burning.

The following analysis shows the chemical character of the clay:

Analysis of Terrace Clay at Oak Hill Pottery.

	Per cent.
Silica (SiO^2),	46.160
Alumina (Al^2O^3),	26.976
Iron oxide (Fe^2O^3),	7.214
Titanic acid ($Ti O^2$),	.740
Lime (CaO),	2.210
Magnesia (MgO),	1.520

	Per cent.
Alkalies,	3.246
Water,	11.220
Total,	99.286

The clay is thoroughly washed, screened and filtered through a hydraulic filter press. It is then tempered carefully in a pug mill, when it is ready for use. The pots are all joined in plaster-of-Paris mold, a much speedier process than the old method of turning by hand. The accompanying illustration (fig. 15) shows the process of jolly pots, which is in no way different from the process in other potteries. One boy cuts the clay into lumps of the proper size and puts it into the mold, another puts the mold on the revolving plate, inserts the end of a jointed lever inside the mold. The centrifugal motion presses the clay firmly against the mold which shapes the outside of the pot, the lever or pull-down (see fig. 1) scrapes out the interior of the pot, the entire process being much shorter than the telling of it. A third boy takes the mold containing the pot to the drying shelves where after drying a certain time it is removed from the mold and further dried before putting it into the kiln to be burnt. One man with his two helpers will jolly about 4,000 pots per day.

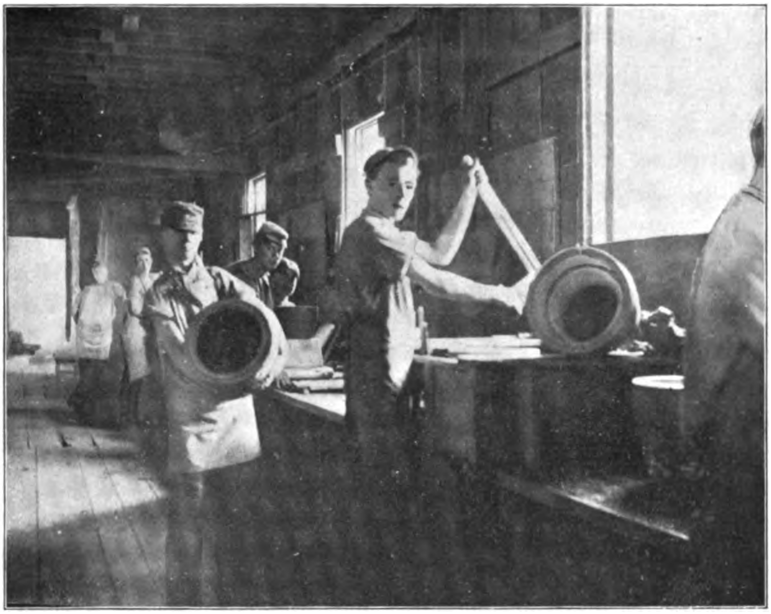

Fig. 15. View showing the method of jollying flower pots.

With the exception of the small pottery on the South Side, Pittsburgh, described elsewhere, this is said to be the only flower pot works in western Pennsylvania. Their largest markets, however, are in the east, although they ship a great many pots to Indiana, Iowa and Virginia.

The works are situated on the terrace 100 feet above the railway and 125 feet above Beaver river. There is an inclined railway from the works to the P., F. W. & C. R. R., on which the ware is transferred and coal for the works brought up.

The Beaver Valley Pottery Co.—The Beaver Valley Pottery Co., Mr. Brewer, manager, operated a factory in the Block House run valley for several years, making yellow washboards. The works were said to be in operation about four years and have now (1897) been idle two years. They put a great many yellow washboards on the market during that time and experimented on glazed tiles, sinks, etc., but apparently not with much success, as the company failed and the works passed into other hands.

Mr. Brewer, the manager of the above company, has been experimenting in different lines, and now has some very handsome enameled tiles and brick which he says he can make successfully. He has recently patented a gurgless jug and has applied the same principle to bottles, glass jars and oil cans.

Messrs. Martin and Linton have leased the old "E. S. & B." pottery, the oldest pottery in the valley, that stands on the hillside above the New Brighton pottery. They expect to begin in a few days (September 1, 1897) to manufacture washboards and yellow ware.

The Mayer Pottery Co. (Limited), Beaver Falls, Pa.—The Mayer Pottery Co. makes plain white and decorated ware, such as dishes and table ware of all kinds. The works were established in 1880 and have been carried on prosperously since that time. They were entirely destroyed by fire last year, 1896, but were at once rebuilt and are again in successful operation. The works are managed by the two Mayer brothers, Joseph and Ernest, both able business men and skilled in the work. Their father was a skilled and progressive potter, constantly experimenting for improvements in his work, the results of which experiments he had kept in a very systematic manner. His son Mr. Ernest Mayer continued the same line of experimental work, but unfortunately the fire last year destroyed all the records of many years work. Mr. Mayer is taking up again this systematic study of clays, and it is hoped that the results of his experiments may be given to the scientific world when they cease to have a trade value to him.

They make semi-vitreous china, under-glaze printed ware, enamel decorated ware and colored glaze ware, all of which require a fine grade of clay, finer than the native clay.

The body of the ware they make is from kaolin from Delaware and Chester counties, Pennsylvania, Florida and North Carolina, and some of the plastic or ball clay is imported from England, but experiments now in progress are expected to confirm the fact that the imported clays can be nearly if not entirely dispensed with and clay from Jefferson county, Mo., used in its place. In the manufacture of white earthenware, the fact of the use of flint and feldspar is often entirely overlooked, and great stress laid on the clay item. Flint is used in the manufacture in larger proportion than any single item, and is usually mixed in the proportion of about 35 to 40 per cent. The flint they use is from Illinois and the feldspar from Pennsylvania. The body used by them is in round figures: flint, 35 per cent.; kaolin, 35 per cent.; plastic or ball clay, 16 per cent.; feldspar, 14 per cent.

They have five kilns and employ about 100 men, boys and girls, and turn out a great deal of fine table ware, which is shipped to all parts of the United States.

The Fallston Pottery Co.—The works of the Fallston Pottery Co. are situated on the east side of Brady's Run, about half a mile west of the village of Fallston. They are not in operation at present and nothing could be learned in regard to the time they were in operation. For some cause unknown the company failed and the works have been standing idle for several months at least. There is considerable ware in stock; light-colored stoneware similar in appearance to that manufactured in the potteries at New Brighton.

They used clay from the Lower Kittanning bed, the same as that used at the other potteries, and have also opened a bed at a lower horizon that appears to correspond with the Clarion bed. This bed is 12 to 14 feet thick and is apparently a good quality of potters' clay. How extensively it was used or with what success is not known, as none of the company or operators could be found.

Keystone Pottery Co.—Wm. Miller and sons, large lumber dealers at Rochester, formerly operated a pottery on the east side of Rochester. The pottery was in operation five and a half years, from 1890 to 1895. In June, 1895, the buildings were destroyed by fire and have not been rebuilt. The statement of the company is that the prices were then so low that it would not pay to rebuild the works.

There were three kilns and they made different kinds of stoneware like that made at New Brighton, having an especially large trade in ink bottles.

The works are situated on the banks of the Ohio river and close to the P., F. W. & C. R. R., thus having excellent shipping facilities both by rail and by water. Like the other potteries their principal trade was in the eastern states, Portland, Me., being one of the largest shipping points. They also shipped to Cincinnati, Chicago and as far west as California.

They used clay from the Lower Kittanning bed, the same geological bed as that used at New Brighton. The clay was mined from a drift in the bluff about 50 feet above the works. Some of the shale underlying the clay was used to mix with it in making the yellow ware.

No particulars further than those given in the historical sketch are available concerning the potteries said to have been operated at Vanport and Bridgewater many years ago.

The Beaver Falls Art Tile Co.—The Beaver Falls Art Tile Co. started their works at Beaver Falls in February, 1887, with J. M. May, chairman, and F. W. Walker, secretary and treasurer. The works are situated near the middle of the town of Beaver Falls, close to the P., F. W. & C. R. R.

They make decorative or glazed tile of great variety in sizes and colors. They carry a large stock on hand so that they can in most cases fill orders on their receipt.

They use clay from different points but the bulk of it, their estimate is 85 per cent. of the whole, is obtained from the clay mines at Block House run, New Brighton, in the New Brighton or Lower Kittanning beds, the same clay as that used in the New Brighton potteries. Where a white body is desired as in the white tiles, a purer kaolin is needed, which is obtained in part from Chester and Delaware counties, this State, and in part from Florida and North Carolina. The latter are said to burn whiter than the Pennsylvania kaolins. The clay is finely ground and screened through very fine screens, 200 meshes to the inch. It is thoroughly washed and passed through the hydraulic filter press in a manner similar to that in the potteries. Unlike the potters, however, they do not mix the clay wet to a plastic state but mould it dry. The nearly dry clay is put into the mould and stamped with a die forced down upon it by a screw. The tiles are first burnt in a biscuit kiln and then dipped into the proper glazing mixture to give them the color desired and then reburnt in the glazing kiln. Two biscuit kilns and three glazing kilns are in use. They make a great many different shades, which are all produced by various admixtures of the different metallic oxides. The mixing of these different colored glazes is an art requiring much experience and skill, and receipts for mixing them are carefully guarded. Mr. Walker, who has this part of the work in charge, has made a careful study of it, and has produced some very pleasing results. Like Mr. Mayer, he is a scientific experimenter, constantly working for new colors, new designs and new methods. His ingenuity and watchful care is shown in other ways, one of which is the unique single track, overhead, carrier system, used in transporting the ware from one point to another in the works.

The ware is all burnt in saggars, which are made largely out of New Brighton clay.

The company had a very handsome and instructive exhibit at the World's Fair, which with the other State exhibits is now at the State College. It contains a representative collection of the different colored tiles arranged in figures, and accompanied with the raw products and the different glazes before and after burning, showing the various stages of manufacture from the raw clay to the finished product. It attracts much attention in the collection and ranks among the most interesting exhibits of the State at the World's Fair in 1893.

CHAPTER IV.

FIRE-CLAYS AND FIRE-CLAY INDUSTRIES INCLUDING OTHER REFRACTORY MATERIALS.

The fire-clays and their industries reach first rank in Pennsylvania. The statistical returns for 1896 show that Pennsylvania produces not only more fire-brick than any of the other states, but almost as much as all of the others combined.

Value of the fire-brick product in the United States in 1896:*

Pennsylvania,	$2,083,414
All other states,	2,823,509

Pennsylvania not only produces more fire-brick than any other state, but uses more than any other state, which is due partly to her great manufacturing interests, the huge furnaces, the hundreds of mills, and thousands of coke ovens demanding a constantly increasing supply of refractory materials. New Jersey ranks next to Pennsylvania in the value of its fire-brick products, which amounted to $604,983 in 1896.

Definition.—The term fire-clay is used with different significations by different persons. It properly signifies a clay that will stand the fire. But as any clay will stand a moderate degree of heat, and no clay is absolutely infusible, the limitation of the term fire-clay naturally becomes a question of the degree of heat the clay will stand without fusion. As most fire-clays are light colored, generally blue, it is customary in some places to call all blue clays fire-clays, and thus distinguish them from the common yellow or red brick clays. Nearly all fire-clays, whatever their color in the raw state, burn to a light nearly white color, hence with some persons any clay that burns white or nearly so, is called a fire-clay. In both cases the distinction is based on the relative amount and nature of the iron in the clay, a distinction which may frequently lead to error, as while iron is one of the most common fluxes, there are others, such as the alkalies and alkaline earths which affect the fusibility as much as the iron, but do not change the color.

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*Mineral Resources of the U. S., published by the U. S. Geol. Surv.

A blue clay might have a large percentage of iron in the ferrous condition and burn a bright red. It is possible on the other hand to burn a clay in such a manner that it may still remain light colored, but be none the less fusible. While it is true that many fire-clays are blue clays and most of them are light colored after burning, it does not always follow that all blue clays or all clays that burn light are fire-clays in the sense of being highly refractory clays.

One writer says* a fire-clay to be refractory should not contain over four per cent. of impurities. But this is rather misleading, as it depends on the character of the impurity and how it is diffused, as four per cent. of soda or potash would have more effect on the fusibility of the clay than double that amount of sand or titanic oxide.

The line might be drawn on the temperature at which the clay fuses, which would be the most accurate and logical distinction. The objection to such a distinction is that, owing to the difficulty in gauging high temperatures, it is not a ready or easy method of application, and such distinctions as those first mentioned, based on color, will continue to be used because of the ease of application. On the basis of temperature it will be necessary to set one or more arbitrary standards. If a low temperature is taken then it will be necessary to establish another to distinguish the high grade refractory clays from the low grade. One writer† says 2500 degrees Fahrenheit, but there is no commonly adopted standard as yet. When the working of the clays is put on a more scientific basis, and the methods of pyrometry are improved, all the fire-clays and other high grade clays will be tested and gauged on a fusion basis, and each clay labelled with its melting point. Arbitrary standards must be taken as there is frequently a wide range of temperature between the first evidence of fusion and the complete melting. The element of time also enters to some extent. These difficulties can be brought within practical limits so that it will be possible to designate a clay by its fusing points in a manner that will tell the intelligent manufacturer of the clay and the user of the product whether it will or will not suit his purpose.

As capital in the clay industries centralizes more, as it is doing in all lines of trade, the clays will be studied and classified more thoroughly and used in a more effective manner, as has been done in the iron industry. The iron master of 50 years ago would have smiled in derision at the care and precautions used at the large furnaces of the present day, yet a better and more uniform grade of iron is made to-day in the large plants than was made in the small ones, and made with less cost and less waste.

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*Clay Industries of N. Y. Bulletin of State Museum, Vol. 3, No. 12, March, '95, p. 223.

†Wheeler-Missouri Geol. Surv., Vol. XI, clay deposits, page 133.

There is no sharp distinction between fire-clay and potter's clay. While in general the potter's clay need not be so refractory as the fire-clay, it sometimes happens that both are taken from the same mine, as is done at New Brighton in western Pennsylvania, and other localities.

Varieties of fire-clay.—The different grades of fire-clay are divided into two quite distinct classes: (1) the flint or hard clays and (2) the plastic or soft clays. The flint clay differs from all other clays in its unique character, which is indicated by its name. It is quite hard and brittle, with a conchoidal fracture and looking not unlike flint in its apparent hardness* and fracture. One accustomed only to the soft common brick or potter's clay, would not suspect the clayey character of the flint, nor would he suspect it, should he attempt to work it like other clays, as it lacks that useful and characteristic property common to all other clays, namely plasticity. It does not slack like other clays when placed in water nor even when exposed to the weather. Weathering reduces it to a granular sandy mass, but devoid of plasticity. Nor is it rendered plastic by the ordinary grinding processes. It is claimed that prolonged and excessive grinding will induce a faint plasticity, but it is certainly not practical to render it sufficiently plastic to work alone, and it can only be used in the manufacture of ware of any kind by mixing it with a bond of plastic clay or other material.

Chemically the flint clays come nearer the kaolin base than almost any other clay. As they occur in nature they are purer kaolins than any of the so-called kaolin deposits, as all kaolins have to be washed before using to rid them of their impurities, while the flint clay goes direct from the mines to the grinding pan undergoing no separating process except that done by hand in the mining which is practically limited to picking out the ore balls. They are characterized by a higher percentage of alumina than other clays, in fact some of them have a higher percentage than the pure kaolin base, as may be seen by comparing the analyses in chapter IX. Sometimes they have a lower and sometimes a higher percentage of water than kaolin, and as already stated a lower percentage of fluxes or fusing material than any other of the natural clays. Hence they are used for fabricating the most refractory wares.

The flint clay rarely shows evidence of lamination, but its otherwise massive structure is broken by numerous vertical joints which separate the clay into irregular prismatic masses. This jointed structure of the clay combined with its dark blue-gray color, hardness and compact texture, gives it a resemblance to the basaltic rocks which appearance is still further strengthened by the occasional concentric weathering so characteristic of the basalts and diabases.

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*Its real hardness is less than calcite; that is, less than 3 in a scale in which flint is 7.

The concentric weathering is most marked in the "ore balls" or the secretions of iron oxide in the clays as these nearly all show the concentric structure on weathering. It does not appear probable, however, that the iron causes the concentric character, as the same phenomenon occurs where there is but little or no iron. So that apparently the concentric structure antedates the deposit of the iron. In the accompanying illustration, Fig. 16, which is a view in one of the Bolivar clay pits, there is very little iron, although elsewhere in the same vicinity the ore balls are numerous and nearly all show the concentric weathering.*

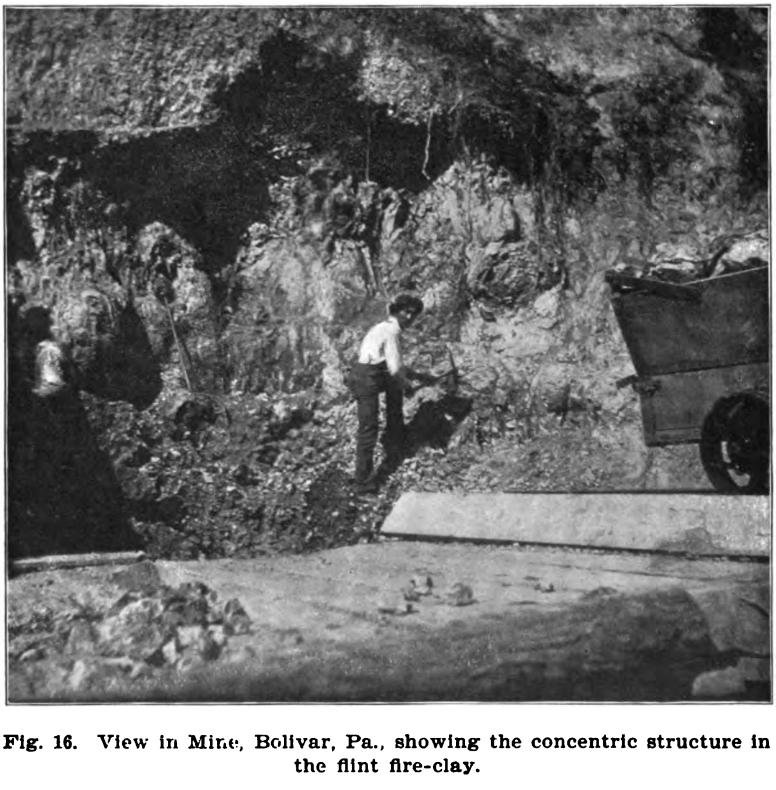

Fig. 16. View in Mine, Bolivar, Pa., showing the concentric structure in the flint fire-clay.

Flint clay varies in color from light gray to nearly black, and frequently has a brown surface stain of iron oxide. In most of the mines there is considerable iron oxide or iron carbonate, known among the miners as ore balls. Near the surface they are nearly always iron oxide and in the interior of the bed they are commonly iron carbonate. The oxide balls are readily distinguished by their color and weight and the carbonate ones by their weight. It is necessary to pick out these ore balls by hand in the mining and working of the clay. Where the iron occurs in numerous small secretions, or in finely diffused condition, so that it cannot be removed by hand, the clay is useless for high grade refractory ware.

The mode of occurrence of the flint clays is in no wise different from the plastic, both occuring as sedimentary beds interstratified with the coal beds, sandstones and shales of the coal measures, sometimes immediately underlying the coal and sometimes separated from the coal by shale or sandstone. The beds vary in thickness from a few inches to 25 feet, sometimes all flint clay, but frequently associated with plastic clay. Where the two occur together, the plastic clay may lie underneath the hard clay or it may lie on top, sometimes both ways in the same mine. Sometimes the bed will be nearly all flint clay, sometimes nearly all plastic clay.

To those familiar with the flint clay mines in Pennsylvania, it would be interesting to know the mode of its occurrence in Missouri. It is there never formed in stratified beds or sheets that extend over large areas as in the case of plastic fire-clays and shales. They have an irregular, massive, jointed structure which seldom suggests a water-laid deposit. They always occur in limestone formations and occupy local sink holes or crater-like depressions, which in size and shape are identical with the numerous sinkholes so characteristic of many of the Missouri limestone districts. The basins occupied by the flint clay vary from 50 to 200 feet in diameter and from 15 to 50 feet in

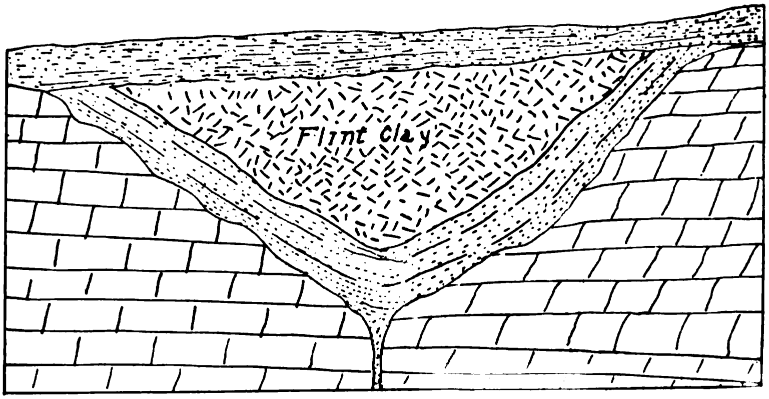

Fig. 17. Showing mode of occurrence of flint fire-clay in Missouri. The clay occurs in sink-holes in limestone, surrounded by sandstone.—Mo. Geol. Surv., Vol. XI.

depth.† The accompanying illustration (Fig. 17) shows the mode of its occurrence.

Plastic clay.—The plastic fire-clays differ from the flint clays in that they become plastic when mixed with water. While never so hard as the true flint clays, they are frequently so hard as to require drilling and blasting to remove them economically from the bed, but on exposure to the weather they rapidly crumble into a soft plastic clay. It is found in most cases to be economical to mine the clay several months or a year before using it, as after exposure it is not only more plastic, but is much softer and can be ground and mixed much more economically.

As a rule the percentage of water in the plastic clay is lower than in the flint clay, the per cent. of fluxing ingredients (alkali, iron, lime and magnesia) is higher, and they fuse more readily. Where the most refractory brick is wanted the least possible quantity of plastic clay is used that will bond the other to the required strength.

Geological position of fire-clays.—In western Pennsylvania the workable flint clay deposits appear to be limited to the lower coal measures, or the Allegheny river series. Plastic clays and shales occur in the higher coal measures in both the lower barren measures and the upper productive or Monongahela series, but no deposits of flint clay were observed by the writer above the horizon of the Upper Freeport or E coal bed. Indeed very little plastic clay is worked from the higher coal measures, nor do such valuable beds occur there as in the lower series.

The most valuable bed of flint clay, the one worked most extensively in western Pennsylvania, is that near the top of the lower productive series, and known as the Bolivar or Upper Freeport clay, lying but a few feet below the Upper Freeport coal bed. At Bolivar it is 20 feet to 25 feet thick and varies greatly throughout the region. This bed is best developed along the west slope of the Chestnut ridge and in the Ligonier valley. Several other beds at lower horizons are locally valuable in many places.

The most valuable bed of plastic fire-clay is that immediately underlying the Lower Kittanning coal, and known as the Kittanning or New Brighton clay. (See p. —.) Many other beds occur at different horizons, and the plastic fire-clays are pretty well distributed throughout the coal measures. The thin bed which forms the clay parting in the Pittsburgh coal seam is utilized to some extent at two places in the Monongahela valley for the manufacture of refractory ware.

The origin of the carboniferous fire-clays appears to be linked with that of the coal beds. Their frequent almost universal occurrence immmediately underlying the coal beds indicates that they formed the bottom of the swamp or bog in which the vegetation forming the coal beds accumulated. The growth and decay of the plant remains extracted the iron and alkalies from this clay soil, leaving it freer from these bases than ordinary clay soils. In swamps at the present time we find in most cases a blue clay or black clay soil in marked contrast to the yellow clays of the dry areas.

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†Clay deposits by H. A. Wheeler Mo. Geol. Surv. Vol. XI, p. 202.

It does not appear so clear why some clays should remain as soft plastic clay and that others should form the hard flint clays. The most plausible explanation that has been given for the flint clays is that the kaolin has crystallized wholly or in large part, and the flat crystal scales have no plasticity. The plastic clays are free from crystals and the minute particles of the clay are held together by the capillary water and yet not so firmly but that they can move rather freely around each other thus giving the clay its plastic property. Why some of it should crystallize and others not is probably due to a textural difference which has not yet been explained.

Possibly metamorphic action due to the uplifting and folding of the strata may have more to do with the change than is ordinarily supposed. Yet there are difficulties in the way of such a supposition. We find in the folded ridges of the mountains more flint clay in the same beds than in the region further west where the strata are less folded. Yet we find beds of soft clay in the mountains in the same hill with flint clay and sometimes in the same mine,and flint clay does occur in Ohio and other Mississippi valley states remote from the mountains. Presure might change the physical properties of the clay making it less plastic but hardly alter its chemical character and make it more refractory.

A preliminary microscopic examination by the writer failed to show any marked difference microscopically between the flint and the plastic clay. By grinding a small quantity of flint clay in an agate mortar for some time I found it be quite plastic. The difference appears to be wholly one of induration. The minute particles in the flint clay are so firmly bound together that water will not separate them or penetrate the spaces between them as in the plastic clays. It may be questioned how much of the induration is due to pressure and how much to the chemical deposit; in all probability both agencies have been at work.

FIRE-CLAY PRODUCTS.

Fire-brick.[*]—Probably more fire-clay goes into brick of different kinds than is used in any other way. The different kinds of fire brick, or those used for different purposes, require different grades of clay mixed in different proportions. Furnace bricks require a high grade

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[*] Fire bricks were formerly limited in their use largely to lining furnaces and cupolas or to refractory purposes. Now they are used in vast quantities for ilding brick and paving brick. This use of fire-clay will be described elsewhere.

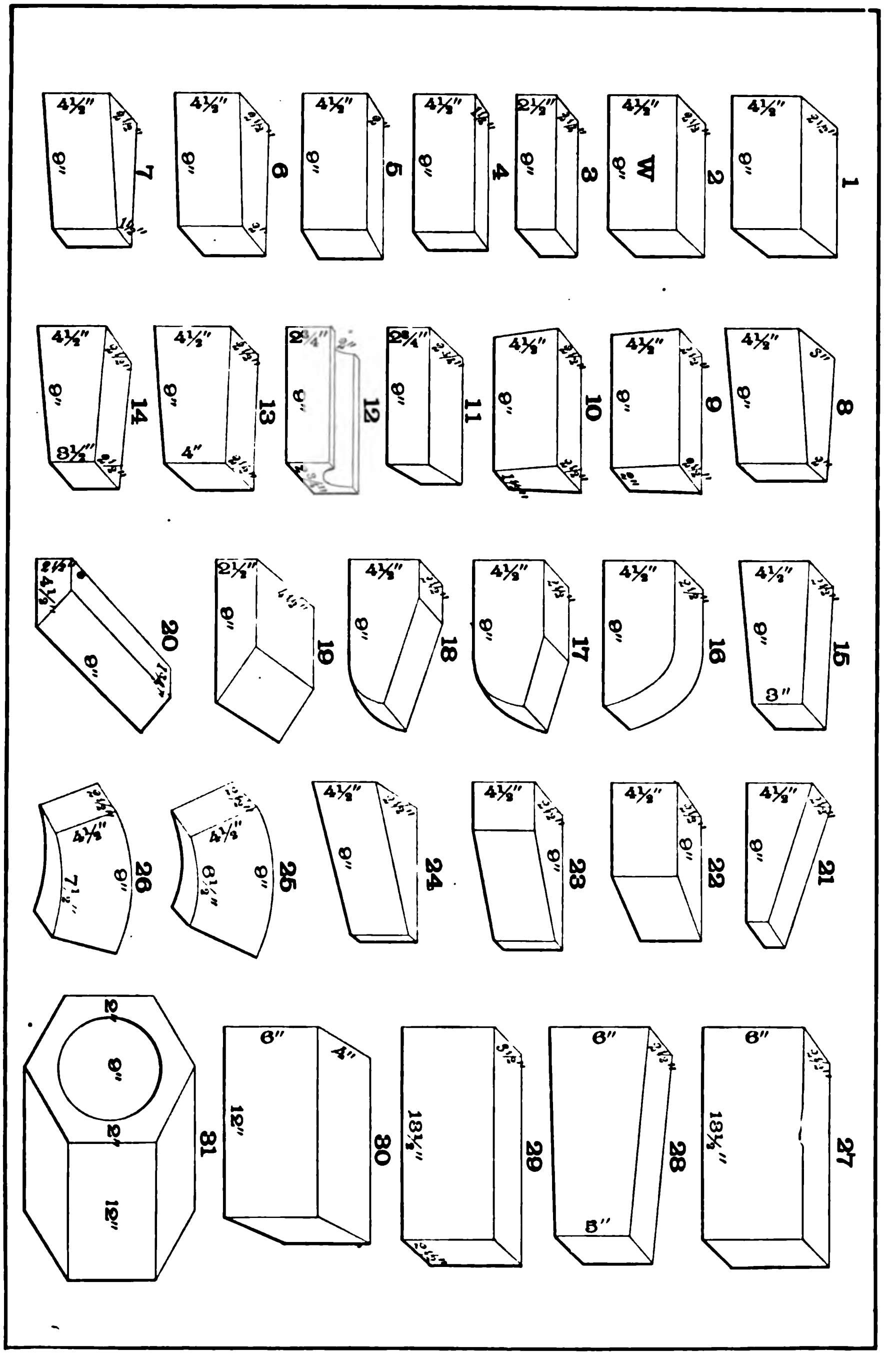

Fig. 18. Some of the common stock shapes of fire brick.

fire-clay but the upper part of the furnace, which is subject to much friction from the charge, requires a different kind of brick from the boshes where there is less friction but much greater heat. Hence the fire brick for the lower part of the furnace is made almost entirely of high grade flint clay using only sufficient plastic clay to hold the flint clay together, while the brick for the upper part contains a large percentage of plastic clay which gives added strength, the rule being that increasing the percentage of plastic clay increases the tensile strength and increasing the percentage of flint clay increases the refractoriness of the brick. The best furnaces use one or more intermediate grades through the middle of the kiln.

Mill brick and tile for use in the foundries, rolling mills and other mills require brick of different grades of refractoriness and abrasive strength. The varieties in (see Fig. 18) shapes, sizes and qualities of furnace and mill brick are truly surprising. This is best shown by giving a list of the standard shapes which are kept in stock by one of the large fire brick works of the district, which is as follows: Stock shapes of fire brick and tile 9 inch square; large 9 inch and small 9 inch; soap; No. 1 and 2 split; Nos. 1, 2 and 3 wedge; Nos. 1 and 2 arch; checker; key or wedge; Nos. 1, 2, 3 and 4 key; Nos. 1, 2 and 3 jamb; Nos. 1, 2 and 3 skew; Nos. 1, 2, 3 neck; 33 inch, 42 inch and 51 inch circle; 42 inch, 48 inch, 60 inch and 72 inch cupola; 13 and ½ inch square; 13 and ½ inch Nos. 2 and 4 key; 13 and ½ inch square gas flue arch; 13 and ½ inch arch 3, 4 and 5 feet in diameter; velvetry tile; stock hole tile; bridge block; Siemens furnace AA, A, B, C, 4, 5, 6 and 3; bevel cover, square cover and arch cover brick; regenerator blocks J, K, L. M and N; regenerator tile 9 sizes; flange or lap tile, 2 sizes; aft boiler tile, 3 sizes; centre boiler tile, 7 sizes; side boiler tile, 4 sizes; grate backs, 10 sizes; slabs, 5 sizes; furnace bottoms, 9 sizes; ladle nozzle, 5 sizes; stopper rod sleeve, 2 sizes and Bessemer tuyere, 4 sizes, making in all 127 different shapes or including the qualities 176 different shapes to be kept in stock.

As can well be imagined, coke oven bricks form a very important part of the trade in southwest Pennsylvania, which is the chief coke-producing region of the United States. The number of fire bricks required to build and keep in repair the thousands of bee hive coke ovens is very great. They do not require such a highly refractory brick as the blast furnace, but one that will stand sudden and violent changes of temperature, as the coke is commonly cooled by turning on a stream of cold water which comes in contact with the red hot bricks of the crown. Several companies make a specialty of coke oven brick and tile.

Locomotive and steamboat tile are made in considerable quantities, and besides supplying the local markets are shipped to distant markets, to the western part of the United States and to foreign countries.

Steel runners, sleeves and nozzles are comparatively new products now used in large quantities in the steel works for running the molten steel to the molds. They make a specialty of this work in the Monongahela valley in the clay from the Pittsburgh coal bed.

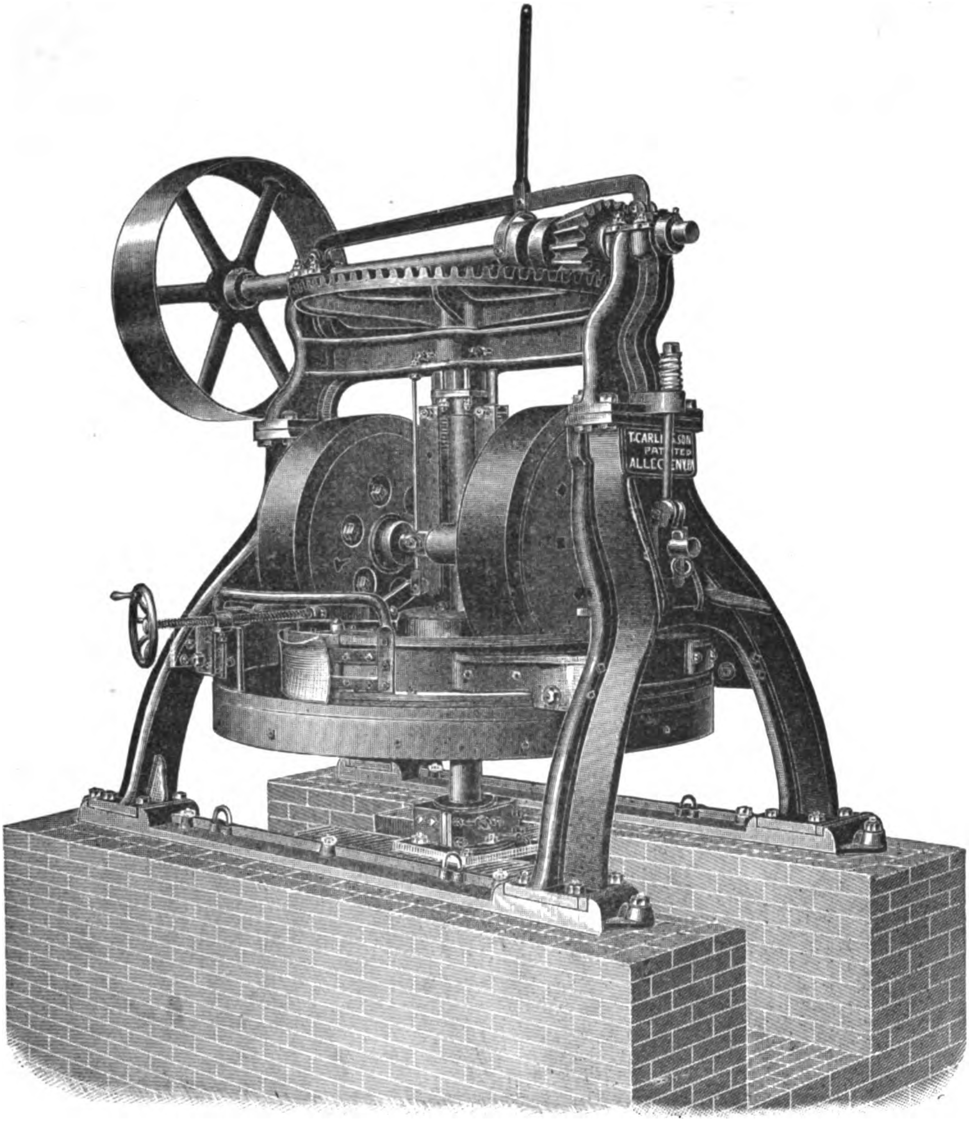

Fig. 19. Wet pan for grinding clay.

Methods of working the clay and machinery used.—There are two methods of removing the clay from the earth; one by stripping the overburden and quarrying from the surface, and one by running in a drift and mining underground. Which of these methods is employed depends on the thickness and character of the strippings, the thickness of the clay and its position in the hill. Sometimes both methods are used together, that is, the clay is worked by stripping at the outcrop back in the hill until the overburden becomes too heavy to remove with profit, when a drift or mine is run in from the face and the process continued under ground.

The mining or quarrying is in nearly all cases done by blasting, in which the blasting auger similar to that used in coal mining is used, where the clay is soft enough to permit its use. After blasting, the clay is loaded on the mine cars and run to the works or to the railway.

For common fire brick where the molding is done by hand, the clay is ordinarily ground and mixed in the wet pan, a heavy revolving iron pan with two very heavy iron rollers revolving inside.

For the flint clays these are made very heavy. (See Fig. 19.) The clays in the proper proportion are dumped into the pan, sufficient water run in for the mix and the machinery set in motion until it is thought to be ground sufficiently, when it is removed to the molding table and another batch put in. There are numerous sizes and styles of the wet pans, but all operate on the same principle. Some are emptied automatically and some by hand.

Where the bricks are molded by machinery, it is necessary to remove all the coarse lumps and have a more uniform consistency than is obtained by the above process. Then the clay is ground in a dry pan and screened. The dry pan resembles in many respects the wet pan, but there is no water put in the pan with the clay and the bottom of the pan is perforated to permit the ground material to filter through. (See Fig. 20.) Rolls and disintegrating machines are sometimes used in place of the dry pan and sometimes in conjunction with it. These are sometimes simple smooth rolls, sometimes conical rolls, sometimes corrugated rolls, and sometimes combinations of rolls with cutters, or even the ordinary rock crusher.

After grinding the clay is elevated, generally by a bucket elevator, and screened, the fineness of the screen depending largely on the kind of ware to be manufactured. The tailings run back to the dry pan or rolls to be reground. The screened clay is run into storage bins from which it can be fed into the pug mill.

Tempering and molding.—Where the clay is ground dry it is tempered or mixed to the right consistency with water, either in a wet pan or a pug mill. The pug mills are of different types, some vertical, and some horizontal, some combined with the molding machine and some separate. See under building bricks, chapter VI.

Most of the manufacturers are emphatic in their statement that good fire brick must be molded by hand and not by machine. The objection to the machine-made fire brick is two-fold: first, that it is too dense, and hence will not yield so readily to extremes of temperature as a more open textured brick; second, the brick is not homogeneous throughout, as the clay is more or less laminated as it is pushed through the die. Both these objections, however, are more applicable to the stiff-mud machines than to the soft-mud machines. So firm is this belief among manufacturers and evidently therefore among the users that most of the oldest and best known dealers manufacture fire brick only by hand even when machines for making building brick are standing idle in the works.

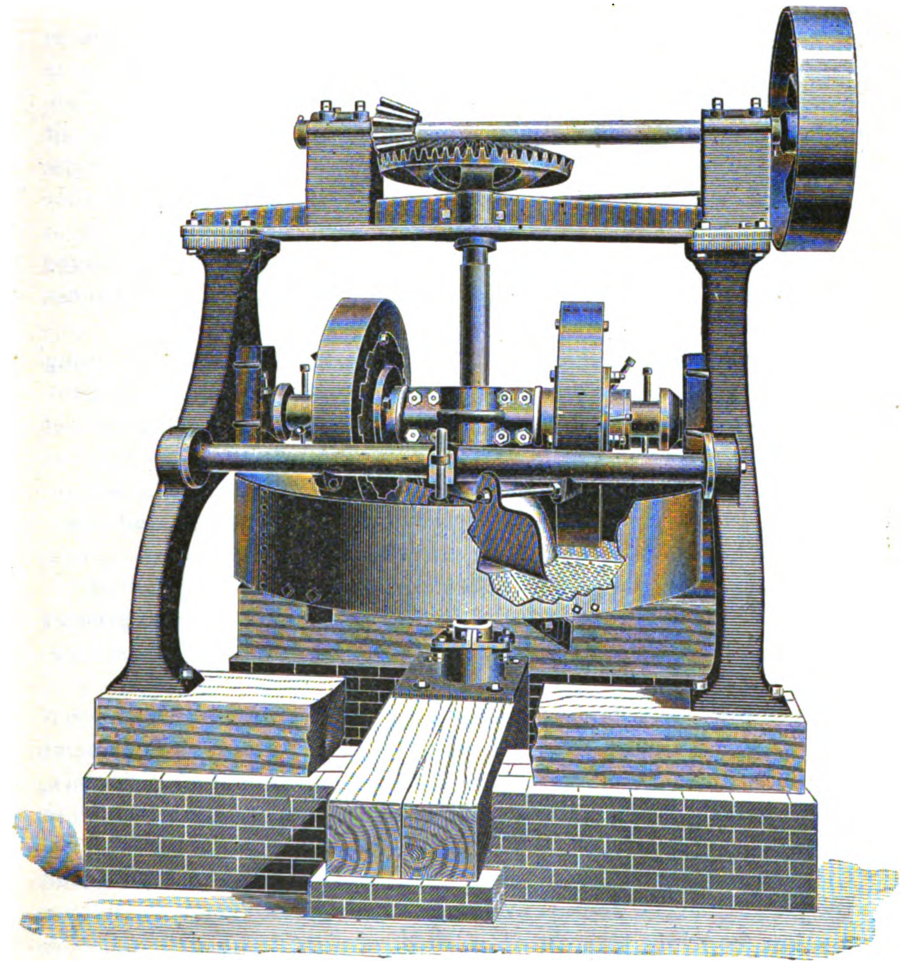

Fig. 20. Dry pan for grinding clay.

Drying, pressing and burning.—Where the bricks are molded by hand, they are dried on a drying floor. The molding tables are placed at the edge of the drying floor and the off-bearers take the bricks from the molder's hands, place them on the drying floor and sand and return the molds. The bricks after drying about half a day are pressed in the repressing machine (see Fig. 22), and returned to the drying floor or sent to the drying kilns. The significance of the term repress is not clear. The reason for the pressing is that the bricks when molded are too soft to retain their form, shape or brands. After a half day's drying they are stiff enough to retain the smooth surface, sharp edges and clear branding of the press. This is commonly done by hand, as it is claimed that the hand press makes a more uniform brick than the steam press. A press crew will handle the same number, 4,000 bricks, as a molding crew. The molding is commonly finished about noon, and the press crew follow, pressing in the afternoon the bricks that were molded in the forenoon. In some places the molding is done in the afternoon and pressed the next morning. The burning is sometimes done in a down-draft, sometimes in an up-draft kiln; they are sometimes burnt hard and sometimes soft. The same care is not necessary in burning fire brick as in many other kinds of ware. If the clay is good and the brick properly molded, it is a good brick whether it be burnt hard or soft. Two companies burn part of their brick in the continuous multiple-chambered kilns. Of the others some prefer the down-draft, and some the up-draft kiln. For description of these see under building brick.

Gas retorts require a high-grade clay, one that will make a strong elastic and highly refractory product, and one that will withstand the chemical action of the vapors and gases from the coal. There is but one firm in western Pennsylvania manufacturing gas retorts at present, and that is Jas. Gardner, Jr., at Lockport, Pa. Retorts were made formerly at other points, but the use of iron retorts and other methods of gas manufacture have diminished the use of clay retorts.

Glass pots or the large pots in which the glass batch is melted, require one of the highest grades of fire-clay, one that requires greater care in selection and preparation than any of the other wares mentioned.

The pot must not only stand the high temperature of the melted glass and the glass furnace, but must also withstand the chemical action of the fluxes, such as soda cake and lead oxide used in the mix, which are much stronger corroding agents than the fluxes of the blast furnace.

The clay is subject to very careful inspection both at the mine and at the factory; every lump is broken up by hand into small fragments and every impurity thrown out. This work is frequently done by women. The same care is taken with the old pots which are broken to pieces and every fragment of slag or impurity carefully chipped off.

As in the lining of a blast furnace, different grades of clay are used in different parts of the pot. Thus the top of the pot has only to withstand the heat and bear its weight while the sides are subject to the weight of the top, the pressure of the liquid and the corroding action of the salt-cake.

The clay is prepared much as in fire brick manufacture, except greater care is used in all the processes, and it is put through an extra process called "sweating," in which the moist clay when mixed for use is covered with blankets and allowed to sweat for several months or a year if possible. It is claimed that this has great influence in the working quality of the clay. By some operators the clay is mixed by tramping it with the bare feet, which it is claimed is far superior to any known mechanical process.

The making of the pot is a slow process, taking weeks, and including the drying, even months. It is thus necessary to keep a considerable stock of pots on hand in order to fill orders with any degree of promptness. The pots are not burnt until they are put in the furnace where they are to be used, and then it is the aim to keep them hot until they are burnt out, generally an interval of several months, as they are liable to crack in cooling.

The pots are all numbered and a record kept of them; when they are burnt out they are sent back to the factory and are used as material in building others. As the larger pots weigh from 3,000 to 4,000 lbs., each, the material is quite an item and the utilization of the old pots quite a saving. Single pots cost from $50 to $60 each.

There are but two factories in western Pennsylvania that manufacture glass pots for the trade. The Pittsburgh Clay Pot Co., on Rebecca street, in Allegheny, and the Phoenix Clay Pot Works, Brushton avenue, Pittsburgh, but many of the large glass companies manufacture their own pots at the glass works, and it forms a very important feature of the industry.

Clay for glass pots is mined at Wymp's Gap and Layton Station, Fayette county and in Cambria, Clarion and Clearfield counties, but a considerable part of the clay used for glass pots in Pennsylvania is imported from Missouri, Kentucky, Germany and England.

It is not only possible but probable that there is abundance of good glass pot clay in Pennsylvania which would be used if its presence and properties were fully known to the pot-makers. But the glass pot is such a large and expensive affair that few manufacturers care to experiment on untried clays, and when they have a clay which answers their purposes they continue to use it even though expensive, thinking it is cheaper than experimenting with untried clays. Equally good clays may have quite different properties requiring different treatment, which generally can be gained only by experience, hence the reluctance of operators to try new clays.

Success in making and using glass pots depends on the following conditions:

1. In having a first class high grade refractory clay.
2. Proper preparation and mixture of the raw and burnt clay. An average is about 8 parts of burnt clay to 7 parts raw clay.
3. Proper handling by the pot-maker.

4. Manner of drying and annealing.

5. The temperature of the furnace, the kind of glass to be melted and the treatment of the pot by the smelter.

Much glass is melted now in large tanks made of iron and lined with blocks of fire-clay.

Crucibles.—Large quantities of fire-clay of different grades are used in the manufacture of crucibles of different kinds. The necessary qualities in crucibles are: 1. They should resist high temperatures without melting or softening in a sensible degree, and should not be so tender while hot as to crumble when grasped by the tongs. 2. In some cases they should resist sudden and great changes of temperature. 3. They should be able in some cases to resist violent corrosive action and permeation of molten metals.

The clay for crucibles must be selected with reference to the use to which the crucible is to be put, and must be ground and mixed with care. As with glass pots, which are only large crucibles, considerable quantities of burnt clay or silica must be mixed with the raw clay to neutralize the shrinkage.

Crucibles are used in the burnt and unburnt condition. Small crucibles are nearly always kiln burnt before they are used. Large crucibles like glass pots or casting pots are not burnt except in usage.

So far as known to the writer, no crucibles except glass pots are manufactured in western Pennsylvania. Many of the crucibles used in the United States are imported from England, France and Germany.

Crucibles are also made of graphite, of clay and graphite, of clay, coke and graphite, of alumina, lime and magnesia.

Stove linings and backs for fire places consume large quantities of medium grade fire-clay.

Besides the refractory uses, fire-clay is used in large quantity as a base or body for paving brick, vitrified building brick, several grades of pottery and hollow ware, and other varieties of ware.

OTHER REFRACTORY MATERIALS AND PRODUCTS.

The use of brick made from fire-clay is partially replaced in certain lines of furnace work by what are known as basic brick and silica brick. The ordinary fire-clay is a nearly neutral substance, but it has been found from experiment that a purely basic substance, or a purely acid one is even more refractory under proper conditions than the neutral substance.

The basic brick are used in the basic process of steel manufacture and are made of magnesia obtained by calcining magnesite. As magnesia is much more expensive than the fire-clay, the magnesia brick are used in comparatively small quantities and only for their basic property, as the magnesia has the power of taking up and fixing the phosphorus to some extent, and steel can be made by this process from iron higher in phosphorus than could be used in a furnace with a neutral or acid lining. Dolomite or the double carbonate of lime and magnesia is used for the same purpose. Evidently the basic lining is limited in its use to processes with a basic slag, as in the presence of acid it quickly fuses.

All of the magnesite used in the eastern and southern states is imported. The only magnesite now quarried in this country is in California and the freight rates are so high that it is cheaper to import the material from Greece and Austria for use in the eastern and southern states than to ship from California, so the western product is used on the western coast.* Magnesite was at one time quarried in eastern Pennsylvania.

Silica brick.—Silica brick have long been used in glass furnaces and in the steel furnaces where steel is made by the acid process. Like the basic brick the first ones used in this country were imported, but now large quantities of silica and sand brick are made in western Pennsylvania. A number of the fire brick manufacturers make silica brick along with common fire brick and a few companies make silica brick alone.

The first silica brick were made by mixing the ground silica with a plastic clay which served as a bond. The silica expands on heating and the clay contracts, hence the bond would be much shattered and the bricks be soft and friable. This method is still used to some extent for certain grades of brick and the product generally called "sand brick." Lime is found to make a stronger bond and is the one commonly used for the "silica brick," as it overcomes in part the defect from shrinkage found in the plastic clay bond. They are molded by hand for the most part, but some are made in the soft-mud machine.

Probably the first silica brick made were the famed Dinas brick (named from Dinas rock in the vale of Neath), manufactured in England in 1822. The refractory power of the material called Dinas clay was known many years before that date and it was used for furnace hearths and linings, but for many years no successful method could be found of manufacturing it into brick. The process of manufacturing the brick was kept a rigid secret for many years, and even at the present time many of the manufacturers assume an air of great secrecy about the method of manufacture.

A material very similar to the "Dinas clay," that is used extensively at Sheffield, is there called ganister. It is supposed to occur at the same geological horizon as the Dinas clay, the millstone grit of the lower coal measures.* The term ganister has come into quite general usage for the siliceous material suitable for silica brick or furnace lining. It is now found and utilized in many localities.

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*On the uses, occurrence, and manufacture of magnesia brick, see The Mineral Industry, N. Y., Vol. II, 1893, and on the manufacture of steel by the basic process the same publication Vol. V, 1896. For analyses, specific gravity and comparative tests on the expansion of American and Grecian magnesite and coke oven tiling, see Mineral Resources of the U. S., 1896, or Trans. Am. Inst. Min. Eng., Sept., '96.

Much of the silica used in western Pennsylvania is Medina sandstone of Silurian age, shipped from Huntingdon and Blair counties. Some local rocks are used at Layton, Bolivar, Black Lick and up the Allegheny river, all of which are sandstones of the coal measures. The following companies manufacture silica brick only: (1) The Wm. Stuart Silica Brick Co., Kingston. (2) The Stuart Fire Brick Co., Layton. (3) Silica Brick Co., Layton (not now in operation). (4) Phoenix Fire Brick Works, Manorville.

The following companies manufacture silica brick along with other fire brick: (1) Reese, Hammond & Co., Bolivar. (2) A. J. Haws & Son, Johnstown. (3) The Burl Fire Brick Co., Black Lick. (4) Harbison & Walker, Pittsburgh. (5) S. Barnes & Co., New Brighton.

In some localities silica rocks are found of such a nature that they can be dressed to the desired shape and used in the furnace without the necessity of first making them into brick. They may be used for furnace hearths or entire furnace linings and are known as firestones. There is a large quarry of such rock at the base of Chestnut Ridge on the National road, about three miles east of Unionville.

Carbon, lime, talc, asbestos and bauxite are other refractory substances, but used in small quantities compared with fire-clay and are hardly competitors in the market with fire-clay. Carbon in the form of graphite or coke is very refractory and used for making crucibles and furnace brick. Some are made of carbon alone and some of carbon and clay mixed. Both kinds are made by Harbison & Walker, Pittsburgh, Pa. Lime is one of the most refractory substances in nature but it is not adapted to many refractory uses on account of its strong affinity for moisture and acids. It is used to some extent for small crucibles and in the oxyhydrogen or lime light. It is used as a bond in the silica brick, not however on account of its refractory power but because it fluxes with the silica, thus binding the grains together.

Alumina is very highly refractory and is used to some extent for manufacturing refractory material. It is more commonly used in the form of the mineral bauxite. Most of the bauxite mined in the United States is obtained in Georgia. Large quantities of it occur in Arkansas near Little Rock, but little commercial use has been made of it as yet.†

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*Percy's Metallurgy, Fuels, Etc., p. 146.

†Arkansas bauxite, Journal of Geology, Vol. V, p. 290, 1897; Georgia bauxites, Bull. No. 2. Geol. Surv. of Georgia and Trans. Am. Inst. of Min. Eng., Vol. 24, p. 234.

CHAPTER V.

THE FIRE-CLAYS AND FIRE-CLAY INDUSTRIES IN WESTERN PENNSYLVANIA.

THE OHIO VALLEY.

There are a number of factories in and near the Beaver valley that make fire brick as a side issue along with their other products; such are the sewer pipe works at New Brighton, the Fallston Fire Brick Co., The Park Fire Clay Co., all of which are described elsewhere under their appropriate headings. (See under potteries, building brick, paving brick.) There are, however, other companies that make fire brick as their chief business; such are described below.

The clays in the Beaver valley region are described under pottery in Chapter III. The same bed of clay, the Lower Kittanning, that supplies the potteries is the one that supplies the fire brick works, the latter being able in some instances at least to work a greater thickness of the clay than the potteries by using more of the sandy material at the base. For the most highly refractory bricks flint clay is shipped in from other points, mostly from Clarion, Clearfield and Cambria counties.

S. Barnes & Co. (Limited.)—The fire brick works of S. Barnes & Co., located on the east side of Beaver river, about a mile above Rochester, is one of the oldest in the State or in the country. Mr. Douglass, the superintendent of the works, has been here for 37 years, and says that he can remember that Mr. Barnes was making fire brick here as early as 1839, which would make the works nearly 60 years old.

This company manufactures fire brick and refractory materials of all kinds. The chief trade and the trade which they seek is that in high grade refractory fire brick for furnaces. Several grades of brick are necessary in a furnace lining: the upper part of the furnace should be lined with a strong brick that will resist abrasion, such a brick as can be made from the clay mined at the works. The lower part of the furnace should be lined with highly refractory material, more refractory than the Beaver valley clay, and which is obtained by shipping in flint clay from other points. Most of that now used is obtained from Clarion county, but some of it has been obtained from Jefferson and Clearfield counties. The flint clays while highly refractory are non-plastic and enough of the plastic native clay is used to form a bond. Between the top and bottom parts of the furnace intermediate grades are used, increasing the proportion of plastic clay as greater abrasive strength is desired, increasing the proportion of flint clay as greater refractoriness is desired. The company carries a large stock of furnace brick on hand and the men in charge have made a study of the needs of the trade in this line, which combined with their long experience give them proficiency in supplying the furnace trade. They also have considerable trade in hot blast stove linings, which they ship to many different points.

They ship large quantities of fire brick to Chicago, some of which is reshipped from there to Minnesota, and other western states.

The bricks are all made by hand and dried on a drying floor. They are burnt with coal in square up-draft kilns.

Ingram & Co.—The fire brick works of Ingram & Co. are situated on the east side of the Pittsburgh, Fort Wayne and Chicago Railroad, between Rochester and New Brighton. They manufacture fire brick only.

They use the Lower Kittanning or New Brighton clay, which is mined at the works. It is ground in a dry pan, elevated, and screened, then mixed in a pug mill and moulded by hand. The works have a normal capacity of 8,000 per day, which are burnt in three kilns, one square kiln holding 50,000, and two round kilns holding 65,000 each.

Their chief market is Pittsburgh and their shipments are made over the Pittsburgh, Fort Wayne and Chicago Railroad.

A. F. Smith & Co.—A. F. Smith & Son own two brick yards at New Brighton, one of which is now (August, '97) in process of construction, and the other is idle. Mr. A. F. Smith's father constructed the latter works about 1845, on the hillside southeast of New Brighton on the southeast side of Block House run. Both building and fire brick were manufactured.

The fire brick works now under construction by Smith & Son are on the northwest side of Block House run, at the entrance to one of their fire-clay mines, about a quarter of a mile below the sewer pipe works. As already stated (Chapter III) Smith & Son ship large quantities of raw fire-clay, both ground and unground, to various points in this country and Canada.

G. Dando & Bro.—The Conway mine, at Conway station, near Freedom, on the Pittsburgh, Fort Wayne and Chicago Railroad has been operated by G. Dando & Bro. for two years. It was formerly operated by Mr. Dunbar and known as the Dunbar mine. They ship ground fire-clay only, none of which is manufactured at the mine. The clay is mined from the same geological bed as that at New Brighton, namely, the New Brighton or Lower Kittanning clay. The bed at Conway station is six to eight feet in thickness and overlain by two feet of coal, which is mined with the clay. The clay lies below the bottom of the valley at this point and both the clay and coal are drawn from the mine up an incline by a stationary engine. The clay is then ground, screened, and shipped as ground clay, most of it going to Pittsburgh.

The clay and coal are both exposed in the cuts along the wagon road a short distance east of the mines.

Welch, Gloninger & Co., Monaca, Pa.—The works of Welch, Gloninger & Co., at Monaca, are on the south side of the Pittsburgh and Lake Erie Railroad, about half a mile below (west of) the Monaca depot. They have been in operation for sixteen years and have built up a large and profitable trade. They have a daily capacity of 20,000.

Their principal trade is in furnace and mill brick, which they ship to the big iron works in Pittsburgh, Cincinnati, Chicago, Cleveland and elsewhere. They are at present (August 31, 1897) filling a large order to Cleveland. Building brick and paving brick are made as a side issue. Their building brick are made in many colors, buff, brown, gray and mottled, and are shipped to many points in the eastern and central states.

They use both the soft-mud and the stiff-mud wire-cut machines. The bricks are dried in a drying tunnel on the cars and transferred to the kiln without extra handling. They use the Osmond and Basset continuous circle kiln, containing sixteen chambers. Nearly all their brick, fire, building and paving are burnt in this kiln.

The clay used is that underlying the Lower Kittanning coal, the same bed as that used at New Brighton. The opening to the mine is on the roadside, on the river bluff, about 30 feet above the mean level of the river. The clay is pushed in cars to the mouth of the mine by hand and is pulled from there by steam power up an incline to the works. They mine about six feet of the clay, leaving the more sandy part at the base. The coal overlying the clay, two feet in thickness, is mined with the clay. Overlying the coal bed there is a thickness of about fifteen feet of shale, two feet of impure fire-clay, four feet of hard, dark shale, two to three feet of soft shale and clay and four inches of coal.

The Stahl Fire Brick Co., Beaver, Pennsylvania.—The works now owned by the Stahl Fire Brick Co. are situated on the south side of the Ohio river, opposite Beaver, and a mile or more below Monaca. Fire brick works are said to have been started here about fifty years ago. Mr. Noss is thought to have been the founder, at least one of the early proprietors. The Pendleton Brothers operated the works for many years, but for ten or twelve years the Stahl Fire Brick Co., of Beaver, has been in possession. The works have not been in operation for three years, but they are now (August, 1897) putting them in repair, expecting to start the manufacture of fire brick at once.

They make a specialty of furnace brick and shapes of many kinds and produce hand-made bricks. The clay is ground in a dry pan, elevated and screened, then mixed in a pug mill, molded by hand and dried on a dry floor, and burnt in an up-draft kiln.

The clay used is the Lower Kittanning or New Brighton fire-clay. and is mined in the hill at the works. The products are mostly shipped by boat on the Ohio river. To ship by rail it is necessary to haul to Monaca.

The company claims to have a heavier bed of clay near the top of the hill and another underneath the Kittanning bed, neither of which has been used.

They experimented for a number of years on porcelain enameled brick, but were not successful and they now confine their attention to fire brick only.

About one mile below Monaca, between the works of the Stahl Fire Brick Co. and Monaca, there is an abandoned fire brick works that is said to belong to L. S. McKallip, of Pittsburgh. The works were started it is said about 35 years ago by French & Quay, French being the active and Quay the silent partner. The business did not succeed as well as expected and French sold out to Mr. McNees, and Quay sold out to Dr. McKinney. Later the Stuart Brothers and Mr. Troop obtained possession. The Stuarts soon sold out to McKallip, who later bought out Troop. After a few years McKallip ceased operations and although he still owns the property the works have been idle it is said about six years, and as might be expected, are sadly out of repair. They made fire brick from the New Brighton or Lower Kittanning bed of clay, that was mined at the works and experimented extensively with enameled brick, even, inducing, it is said, several experienced parties to come from Scotland, but apparently they were not successful in that line.

Welch, Gloninger & Co., Vanport, Pa.—The clay works of Welch, Gloninger & Co., at Vanport, are situated in the narrow space between the Cleveland and Pittsburgh railroad and the river hill, about half a mile below the village of Vanport. They have three rectangular down-draft kilns, each holding about 65,000 brick. They use both the soft-mud and the stiff-mud machines, but most of the brick are made on the stiff-mud wire-cut machines.

The chief trade is in fire brick, but buff, gray, brown and mottled building brick are made. The building brick are re-pressed in the steam power re-press machine.

The clay used is the Lower Kittanning or New Brighton clay, the same as that used in the Beaver Valley. It varies from six to nine feet in thickness, but in most places is about six or seven feet thick. The bed is characterized by numerous "slickenside" seams running in different directions. This feature is more pronounced in this mine than in any of the others observed by the writer in western Pennsylvania. The shale overlying the clay makes an excellent roof, and they have had no trouble from crumbling of the roof, although the mine has been worked for many years, and some of the gangways are two or three times as wide as the average.

The Vanport Brick Co., Vanport, Pa.—The works of the Vanport Brick Co. are said to have been established by Mr. S. R. Mitchell more than 30 years ago. Mr. John Russell, it is said, was the next proprietor and the Vanport Fire Clay Co. had control until the latter part of 1897. Because of financial difficulties the works were idle for two months or more in the summer of 1897. The works are now operated by the Vanport Brick Co.

They use the stiff-mud wire-cut machines with both the steam and hand re-press machines. The daily capacity is about 20,000, the bricks are dried in a steam drying room and burnt in round down-draft kilns, of which they have five.

Probably their largest trade is in building brick, yet they make many fire bricks and some paving bricks.

The clay used comes from the Lower Kittanning bed which is said to be 11 to 12 feet thick. The mouth of the drift at the head of the incline above the works shows a thickness of about 10 feet of clay overlain by 20 inches of sulphurous coal overlain in turn by a soft, yellow brown shale. The clay is underlain by a bed of thin flaggy to shaly sandstone grading into shale. Occasionally some terrace clay is used to give the bricks a darker color.

Mahan postoffice, Park Fire Clay Co.—Near Mahan postoffice, a few hundred yards below the Vanport dam in the Ohio river, is a small fire brick works said to have been purchased recently by the Park Fire Clay Co., of Rochester. It was not in operation at the time of my visit (September 3, 1897), nor was there any one in the vicinity who could give any information concerning it.

There are three small rectangular kilns. The bricks on hand are nearly all light-colored almost white fire bricks, there being a few rough building bricks.

The clay obtained at the works is from the Lower Kittanning bed, the same as that worked at Vanport and in the Beaver valley. The clay at the mouth of the mine is 10 to 12 feet thick overlain by 2 feet of bituminous coal, and closely resembles in appearance that found up the valley.

PITTSBURGH.

A great many fire brick companies both in Pennsylvania and the adjoining states have offices in Pittsburgh, which is probably the greatest fire brick market in the United States, and possibly in the world. However, but four of the companies have works in Pittsburgh, and only two of these produce fire brick, the other two making glass pots. Some of the large glass works also make their own glass pots.

Probably the reason there are not more works in Pittsburgh is the absence of refractory clay in that city. So far as could be ascertained there is no high grade refractory clay mined in Allegheny county, and all that is used is imported from other localities. As the clay nearly always occurs associated with coal beds, it is cheaper, as a rule, to manufacture the brick at the clay mine than to ship the clay to the city.

The Harbison and Walker Co. Star Fire Brick Works.—The works of the Harbison and Walker Co. at 22d and Railroad streets, Pittsburgh, is among the largest fire brick works in the State. The company owns works also at Woodland, Clearfield county and Figart, Cambria county. The total daily capacity of the three works is given as 175,000 or 52,500,000 per year.

The Star works were started in Pittsburgh in 1865 and have been in continuous operation since that time. The clay is obtained from different points in Clarion, Clearfield and Cambria counties. The silica or ganister comes from Point View near Hollidaysburg, Pa. The following analyses of their clays are re-published from the company's circular.

Analyses of Harbison & Walker's Fire-clays.

	Benezet.	Clarion.	Allegheny.
Silica,	45.292	56.300	61.983
Alumina,	40.365	31.693	27.246
Peroxide of Iron,	.510	.881	.351
Lime,	.037	.125	.322
Magnesia,	.015	.000	.148
Alkalies,	.136	.105	2.150
Water,	13.608	10.625	7.500
Loss,	.037	.271	.300

This company manufacturers fire-clay brick of different grades for cupolas, furnaces, coke ovens, rolling mills, gas flues, tiles and blocks for retorts, and blast furnace stove brick. They also manufacture Bessemer converter tuyeres, sleeves and nozzles, Star silica brick for open hearth steel furnaces and gas furnaces; grate backs and stove linings; railroad specialties for locomotive engines; carbon and clay brick and carbon brick, a patented product for lining blast furnaces. The carbon brick are also used in the crucibles and boshes of lead, zinc and copper smelting furnaces. Their trade is not confined to Pennsylvania, but they ship to many distant points in the United States, China and Russia.

They have 72 down-draft kilns, each having a capacity of 35,000, one stack answering for six kilns. Coal is used for burning and the heat from the cooling kilns is discharged into chambers of green brick, with a saving of fuel. They have a continuous kiln having 22 chambers, each holding 17,000 brick. Gas manufactured from coal slack is used in the continuous kiln.

The fire bricks are nearly all made by hand by the usual processes. Most of them are repressed when partially dried. In busy seasons they employ about 15 gangs of molders and repressers. The bricks are dried on drying floors, of which they have two 65x120 and one 65x144 feet.

For certain grades of work the clay is calcined and washed before molding. The calcining is to remove the shrinkage of the clay and the washing is to remove impurities, processes which are rarely if ever used in the smaller works.

The large works, the variety of clay and materials used enable them to manufacture and keep in stock a great variety and quantity of the different refractory materials, and being in the center of the great manufacturing industries of western Pennsylvania where there is a correspondingly great demand for refractory ware, they have a large trade.

Iron City Fire Brick Co.—The Iron City Fire Brick Co. was organized in 1896 by the consolidation of the Iron City Works of W. A. Scott & Son, at Pittsburgh, and W. R. Miller's Sandy Ridge Works, in Centre county. The capacity of both works is given at 15,000,000 fire bricks per annum.

The clay used in the Pittsburgh works is all obtained from other points and shipped in to the works. They make several grades of brick, known under the trade names of: 1. "Iron City," a high grade refractory brick, used in heating, puddling and copper furnaces. 2. "Murtland," a sand brick, for use in necks and clamps of puddling furnaces. 3. "Silica," a silica brick for use in open-hearth furnaces and glass furnaces.

Pittsburgh Clay Pot Co., Rebecca Street, Allegheny, Pa.—The Pittsburgh Clay Pot Company has an extensive trade in all grades of glass pots over all parts of the United States and have learned from experience the grades of clay best adapted to the different varieties of glass. In order to supply all branches of the trade they keep a large stock and variety of pots on hand, the stock valued at about $200,000 at present. This enables them to supply orders promptly, often an important item, as the manufacture of a large glass pot is the work of weeks. They have 80 acres of floor space in their large factory and employ about 150 men and women.

They use fire-clay from Fayette county, some from Armstrong county and some from Clearfield county. The Fayette county clay, they say, is the most satisfactory of any they get from this State. They also use clay from Missouri, Ohio, and West Virginia. They claim that the best clay occurs in the largest quantities in Kentucky, the bed being thirty feet thick, but the transportation is too difficult to permit its transfer with profit. They import some clay from Germany for special grades of work, the yearly imports estimated at 3,000 tons.

Of the glass companies that make their own glass pots, those that were interviewed get most of their clay outside of the State.

The Phoenix Clay Pot Co., at 350 Brushton avenue, Pittsburgh, obtain their clay in Missouri, Ohio and Germany. They manufacture glass pots, tank blocks and furnace brick, their chief markets being Pennsylvania, Indiana, Denver and Canada.

ALLEGHENY VALLEY FIRE-BRICK WORKS.

Outside of the Kiskiminitas-Conemaugh valley described below the only fire brick works visited in the Allegheny valley are the ones at Manorville and Cowanshannoc, both owned by the Phoenix Fire Brick works.†

The two large brick companies at Kittanning, described elsewhere, make some fire brick, but their chief trade is in building brick, paving brick and drain tile. See chapter VII.

Phoenix Fire Brick Works, Cowanshannoc, Pa.—The works are on the east side of the Allegheny river, about three miles north of Kittanning and about a quarter mile below Cowanshannoc station. The mines and works are said to have been operated at this point for about 17 years, how long by the present company is not known.

They make high grade fire brick only and mold by hand. The flint clay is obtained from some point or points further up the valley. The plastic clay, which belongs near the base of the lower coal measures, is mined on the hill about 100 feet above the works and run to the works on a tramway. The products are shipped on the Allegheny Valley Railroad.

Phoenix Fire Brick Works, Manorville, Pa.—The works at Manorville are owned by the same company, Isaac Reese & Sons, as those at Cowanshannoc, described above. The office of the company is located at Manorville. The works at Manorville make only silica brick and the company claims that they were the first to manufacture silica brick in the United States. The plant was established in 1864 by Isaac Reese and re-organized in 1896 as Isaac Reese & Sons. Their silica brick are widely known throughout the State.

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†Lack of time prevented me from ascending the Allegheny Valley above Cowanshannoc. Fire clay is said to be mined and shipped from several points above this.

The silica or ganister is obtained in part from points further up the Allegheny valley and in part from East Tyrone, Blair county. They ship in the limestone and burn the lime at the works.

The bricks are made in hand molds but the clay is handled with shovels instead of by hand, as with other brick, because of the corrosive action of the lime on the flesh.

The works are situated on the Allegheny Valley Railroad at Manorville station, thus having excellent shipping facilities. The Pittsburgh office of the company is in the Lewis block.

For many years fire-clay has been mined and shipped to various points from the Reynolds property, a mile or more north of Kittanning. Clay has been shipped from here at least as early as 1880, how much earlier is not known. No particulars are at hand concerning the industry except such as are given in the Second Pennsylvania Survey* Report.

KISKIMINITAS‡—CONEMAUGH VALLEY.

In the Conemaugh valley there are fire brick works at Salina, Black Lick, Bolivar, Lockport and Johnstown, and fire-clay mines at South Fork and Mineral Point. Some of the oldest and some of the largest fire brick industries in the State are found in this valley.

Kier Bros., Salina, Pa.—At Salina, on the West Pennsylvania Railroad, on the south side of the Kiskiminitas river, is located the fire brick works of Kier Bros., one of the oldest in the State, as they were established in 1845, more than 50 years ago. The Pittsburgh office of the company is in the Stevenson Building.

They manufacture high grade fire brick. They have seven kilns and a daily capacity of 14,000 brick, employing 50 men and boys at the works. Pittsburgh is the chief market, but they ship to Cleveland, Boston navy yard and other points.

They use the clay taken from their own mine at the works. It is at the same geological horizon as the Bolivar clay. The dip of the strata is to the eastward and the drift from which the clay is taken runs down the first hundred feet at an angle of about 15 degrees, then changes to a more nearly horizontal position.

The mine now extends probably lower than the bed of the river and it is necessary to pump the water from the mine. As the main heading follows the dip of the rock and the rooms branch off at a slight up grade, the pumping can all be done from one point, the end of the main heading, the rooms all being comparatively dry.

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*Second Pa. Geol. Survey Report, H-5, p. 244, 1880.

‡The lower course of the river near its confluence with the Allegheny is known as the Kiskiminitas, and the upper part as the Conemaugh.

The clay varies from six to thirteen feet in thickness, including both the hard flint clay and the soft plastic clay. The variation in the thickness of the flint clay is even more marked than that of the entire bed, as it in some places will vary from a thickness of twelve or thirteen feet to two or three in the same room. In some places it lies underneath the soft clay and in some places on top. The flint clay is of good quality, in most places quite clean but in some spots it contains the iron ore balls in considerable numbers. As the ore balls are generally black or nearly black and much heavier than the clay they are readily detected and picked from the clay by hand. The following analyses, made by the Second Pennsylvania Geological Survey, will show the chemical character of the clay:

Analyses of Fire-clay from Kier Bros. mine, Salina, Pa.

	No. I.	No. II.	No. III.	No. IV.	No. V.
Silica,	51.920	47.250	40.720	60.520	55.330
Alumina,	31.640	34.350	37.280	24.970	27.841
Protoxide of iron,	1.134	.693	2.448	1.650	2.916
Titanic acid,	1.160	1.990	2.280	1.220	1.140
Lime,	.030	.580	.520	.910	.580
Magnesia,	.443	.090	.002	trace.	.756
Carbonic acid,	none.	.455	.408	.725	.455
Alkalies,	.402	.261	.570	.218	3.916
Water,	13.490	13.695	15.002	9.395	7.495
	100.219	99.364	99.230	99.608	100.429

No. 5 is the plastic clay; the first four are flint clays. Sample No. 1 was collected by Mr. Platt of the Survey, and the other four were sent in by Kier Bros.

The clay is overlain by shale and limestone (Freeport), above which is a bed of coal four feet thick, the Freeport coal.

Black Lick, Indiana county.—There have been three different fire brick works in operation at or near Black Lick station on the Indiana branch of the West Pennsylvania Railroad, but there is only one at present.

The first yard was started on the east side of Black Lick creek, about one and a half miles above the village of that name. It was opened by Kinter, Robinson and Hadley in 1867. After operating it a few years they sold out to Mr. Giddings, who sold to Mr. Meldron about 1873, who continued to operate them until five or six years ago, when the buildings burned and have not been rebuilt. There were three rectangular kilns, the remains of which are still standing.

The Burl Fire Brick Co.—Mr. Kinter after his severance with the above yard formed a partnership with Mr. Thompson and started the present works in 1873 about 150 yards north of the Black Lick station on the Indiana Branch of the West Pennsylvania railroad. It started under the name of the Black Lick Manufacturing Co. They failed in 1878, and Mr. Meldron, who operated the yard above mentioned, purchased it and continued it under the name of the Black Lick Manufacturing Co. until 1895, when he failed and the works stopped for a time.

They were re-opened in April, 1896, by Messrs. Kline and Mahan, and Mrs. Meldron, under the name of the Burl Fire Brick Co., under which name it is now operating. Owing to the dull times they were closed for two or three months in the summer of 1897, but are now (August, 1897) again in successful operation.

They make fire brick of different kinds, a few buff building brick, some paving brick and some sand brick. Their chief trade is in coke oven brick and in No. 1 furnace and mill brick. For the No. 1 brick they use flint clay from Blue Ball in Clearfield county, mixed with their own plastic clay. For the coke oven brick they use clay from their own mines, both flint and plastic clay. They have made a few buff building brick from their plastic clay and a few paving brick from the plastic clay and shale mixed, and some silica brick from ganister in the form of boulders picked up on the surface about the mines.

The clay is obtained from the mines at the foot of the west slope of Chestnut Ridge about one and a half miles east of the village of Black Lick. The mines have been operated about 30 years and were at one time connected with the works at the railroad by a tramway, but this has fallen into disuse, and for several years the clay has been transported from the mines to the works on wagons.

The clay overlies the Pottsville conglomerate at the base of the lower productive coal measures. It varies in thickness from three to eleven feet, averaging about seven or eight feet. It contains many ore balls or segregations of iron ore, and must all be hand picked before using. In some places the clay is clean and free from iron for a thickness of several feet. In many places it is much seamed and broken, the seams being stained with iron.

The clay has nearly all been obtained by stripping off the overlying material and then removing the clay. As the stripping becomes much thicker in the hill the opening has been pushed along the base of the hill, and starting on the creek bank it is now more than a quarter of a mile long. They attempted at one time to drift into the hill after it, but the plan was not found profitable and was soon abandoned. In most places where it has been worked the clay is covered with sand, clay and sandstone boulders of the terrace deposit. As the opening is carried back into the hill the clay gains a sandstone rock covering. The sandstone boulders from the terrace deposit are used as ganister in making the silica brick.

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The following analyses of the flint clay (No. 1) and the plastic clay (No. II) were made by the Pennsylvania Geological Survey of samples from this mine about 1877:*

Analyses of Fire-clay from Black Lick, Pa.

	I.	II.
Silica,	64.830	68.490
Alumina,	23.950	18.460
Protoxide of iron,	.900	1.566
Titanic acid,	.880	2.150
Lime,	.110	.230
Magnesia,	.187	.551
Alkalies,	.296	2.755
Water, etc.,	9.390	6.310
	100.543	100.512

About 1872, Dr. T. P. Simpson, now of Pittsburgh, is said to have started a brick yard further up Black Lick creek, about two or three miles above the village. He burned a few bricks, but the difficulty of getting them to market is said to have deterred any further work.

The Bolivar clays.—As fire-clay has been mined and manufactured at Bolivar for more than half a century, the clay resources have been pretty well exploited.

The following section was made by the 2d Pa. Geol. Survey about 20 years ago:

Section of Strata at Bolivar.† (Stevenson).

	Feet.	Inches.
Mahoning sandstone,	20	..
Clay,	3	..
Upper Freeport coal,	8	9
Drab fire-clay,	3	..
Sandstone 2 feet, clay and iron ore 3 feet, coal 4 inches, clay and shale 30 feet,	35	4
Sandy shale 25 feet, fissile shale 30 feet,	55	..
Lower Freeport coal 1 foot 5 inches, clay and shale 6 feet, limestone 3 feet,	10	5
Shale 45 feet, Upper Kittanning coal 1 foot 6 inches, fire-clay 1 foot 6 inches, limestone 1 foot 6 inches,	49	6
Concealed,	47	..

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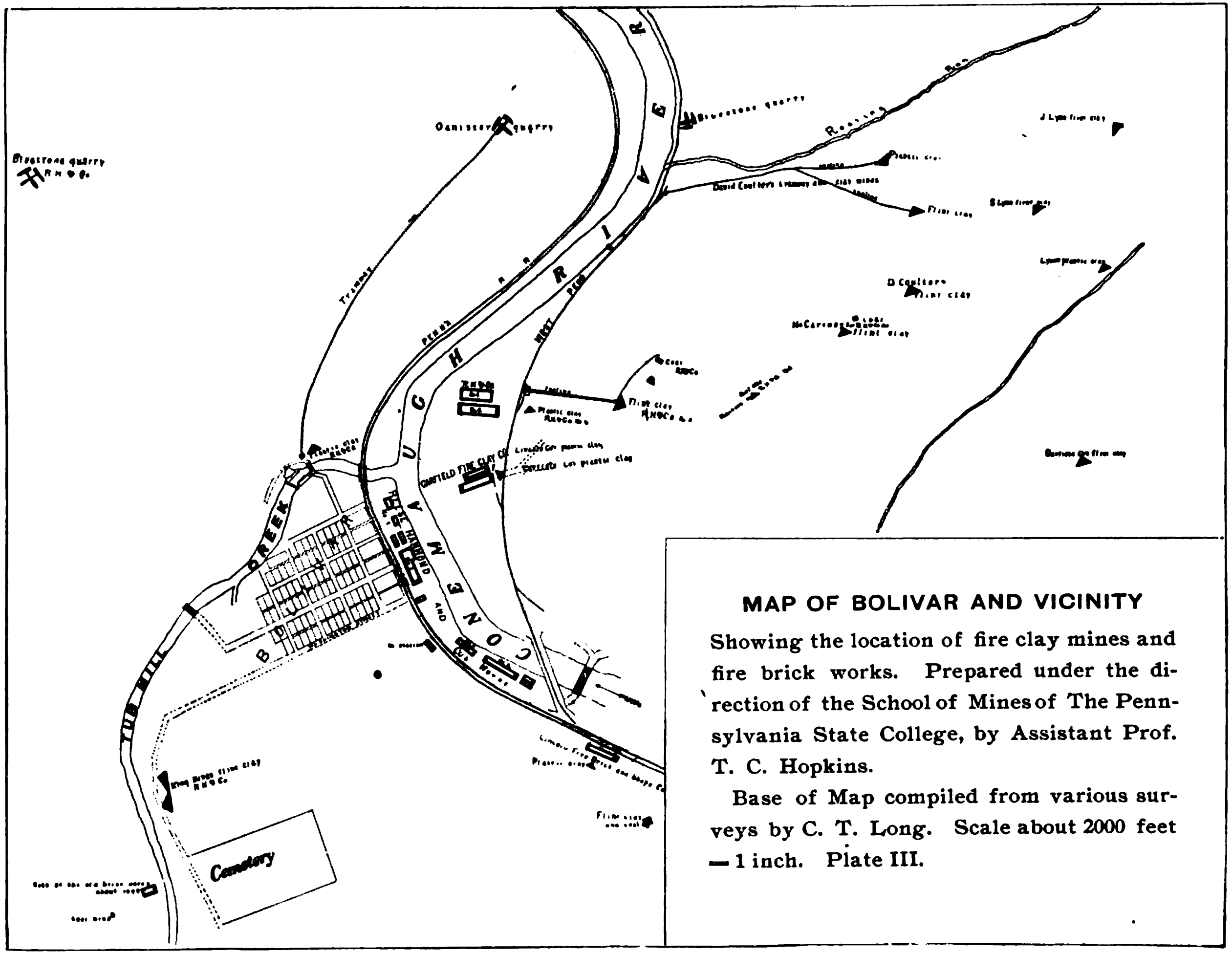
*Second Pa. Geol. Survey, Vol. H4, p. 194.
†Second Pa. Geol. Surv. Rep., 1877, K K K, Ligonier Valley, page 158.



MAP OF BOLIVAR AND VICINITY

Showing the location of fire clay mines and fire brick works. Prepared under the direction of the School of Mines of The Pennsylvania State College, by Assistant Prof. T. C. Hopkins.

Base of Map compiled from various surveys by C. T. Long. Scale about 2000 feet — 1 inch. Plate III.

	Feet.	Inches.
Sandstone 40 feet, shale 12 feet, ...	52	. .
Clarion coal 1 foot 6 inches, fire-clay 2 feet, ...	3	6
Concealed 25 feet, shale 20 [illegible]	45	. .

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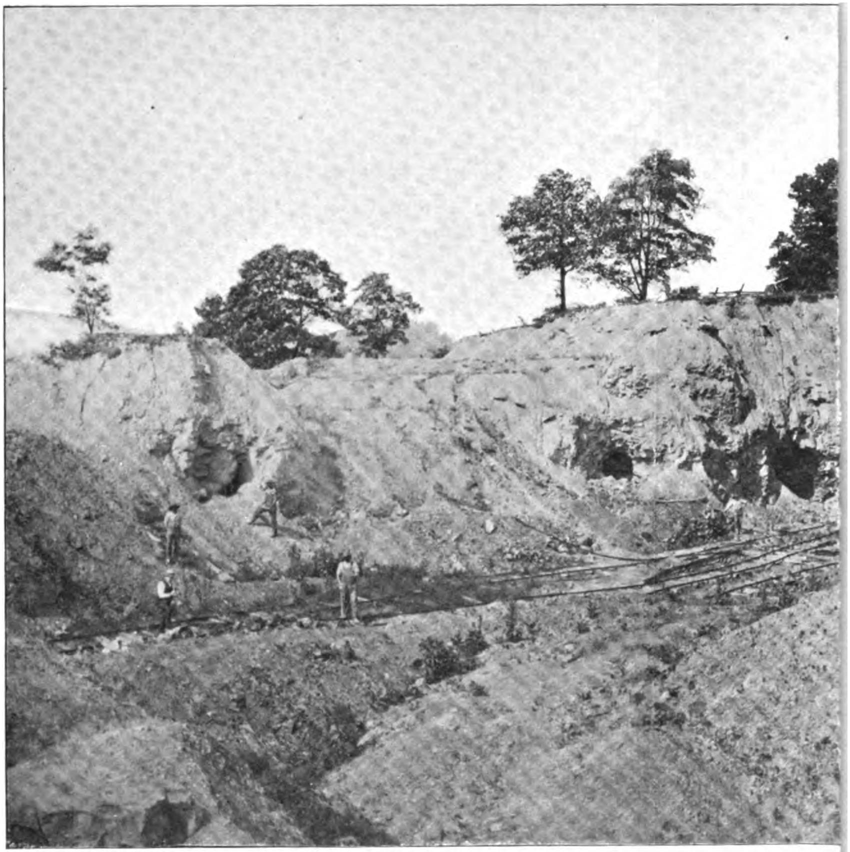
[illegible] prise. The clay is here mined on the hillside more than a hundred feet above the works (see plate III). The bed is 18-20 feet thick and over-



View of the flint fire-clay quarry on the King property, Bolivar, Pa, The c

	Feet.	Inches.
Sandstone 40 feet, shale 12 feet,	52	..
Clarion coal 1 foot 6 inches, fire-clay 2 feet,	3	6
Concealed 25 feet, shale 20 feet,	45	..
Concealed 35, Brookville coal blossom, shale 15 feet,	50	..
Pottsville conglomerate,	..	..

This section will give the general order of succession of the strata, but not a very accurate idea of the thickness of the different beds at the present workings. In the various openings examined by the writer during the past summer all the clay beds that have been worked show a greater thickness than is designated on the section. There is also such a variation in thickness of the intervening beds that it is in places difficult to correlate the beds with those on this section. This may be due in large measure to local variations both in the character and in the thickness of the strata.

The most important bed of clay is that underlying the Upper Freeport or E bed of coal and widely known throughout the State as the Bolivar clay. It varies greatly in thickness, ranging from six to twenty-five feet at different points in the State. Practically all the flint clay used at and shipped from Bolivar, except the little shipped in from other points, comes from this bed.

On the south side of the river it has been mined extensively over a large area on the King tract, owned and operated by Reese, Hammond & Co., and known as their "King Mines," about half a mile southeast of Bolivar, on the slope east of Tub Mill creek (see plate III), near the base of the ridge, where it has been worked for many years, at present on a small scale compared with the operations of former years. The clay was formerly obtained by drifting into the bed in underground workings, but lately the overburden has been removed and most of the clay quarried from the surface, showing a face of clay 18-20 feet in thickness. The clay contains much iron oxide in the form of nodular secretions or segregations, known among the mining men as "ore balls." So abundant are these in certain spots as to give to the quarry the appearance of an iron mine. The ore is in general more abundant in the upper part of the clay bed than in the lower part, and most abundant near the outcrop of the clay. The ore balls are readily distinguished from the clay by their color and weight and are picked out by hand in the mining. The clay is transported on trucks on a tramway to the edge of the village, about half way to the works, and the remaining distance by wagon. See plate IV for view of this mine.

Another point south of the river where the flint clay is mined is on the property of the Lincoln Co., formerly known as the Enterprise. The clay is here mined on the hillside more than a hundred feet above the works (see plate III). The bed is 18-20 feet thick and overlain by about eight feet of shale and "soapstone" followed by six feet of coal. The clay is obtained by underground working. In some places the entire thickness of the clay is removed and in others only the upper part, about six to eight feet thick, which is quite dark in color and is called the "black clay." It is thought to be of superior quality to the lower or lighter colored part of the bed. In one place in the clay mine an inclined opening has been made from the clay mine up through the overlying shale to the coal, which is run down on an inclined track and brought out at the same opening as the clay. This opening is on a bench of the hill several hundred yards distant from the works and the clay is run in cars on a tramway along the bench of the hill to the head of the incline, where it is run down to the works by gravity.

On the northeast side of the Conemaugh river, in Indiana county, opposite Bolivar, this upper clay bed has been worked in a number of places, as shown on plate III. The opening which is worked most extensively at the present time (1897) is that belonging to Reese, Hammond & Co., recently opened on the point of the hill overlooking the West Penn Railroad, to which there is an inclined railway direct from the clay quarry. Clay was formerly mined at this point from shallow drifts or underground workings, but the company is now removing the overburden and quarrying from the surface. At present only the high grade clay is used, the other being thrown over the dump. The aim is as soon as the new paving and building brick works are completed to utilize all or at least the greater part of the material in the different grades of brick. The present face shows about 22 feet of flint clay, the upper few feet containing much iron, overlain by four to five feet of plastic clay, followed by seven to eight feet of coal. While part of this is now waste material, all of it, except possibly the iron ore, can be utilized to good advantage in the manufacture of different kinds of brick, and the company expects to do so at an early day. The coal is of good quality and can all be used in the works. At present the coal is mined two or three hundred yards further north, where it has a better roof. It is brought on a tramway to the clay mine and lowered to the railway on the same incline as the clay. Part of the material overlying the coal can be used, and the only limit to the extent of the surface workings will be a thickness of the overlying sandstone too great to be removed economically, only sandy soil and boulders having been removed so far. However, should this overlying sandstone prove to be good building stone or even good ganister for siliceous brick it may more than pay for its removal. Under any condition the supply of material is scarcely limited as the supply obtainable by extending the work along the slope is almost inexhaustible, to say nothing of the possibilities by mining underground. See plate V. and fig. 16 for views in this clay mine.

PLATE V.

is about 22 feet thick overlain by impure clay, coal, and sandstone.

companies above mentioned. Reese, Hammond & Co. mine it in two places, one near the mouth of Tub Mill creek on the south side of the river, one on the north side of the river in the hill below their flint clay mine No. 3. The Garfield and the Lincoln companies each mine the clay near the Garfield works, both running their clay from the same opening under the railway. David Coulter mines it on the same hillside. with his flint clay on Roaring Run, at about 175 feet lower level. and runs it to the railway on the same tramway.

This bed of plastic clay really consists of two beds known locally as the upper soft clay and the lower vein, but in one opening, that of Reese. Hammond & Co. No. 4 on the north side of the river. the material between the two parts is sufficiently thin to permit the working of both beds together. In this mine the material between the two clay beds dwindles to but a few feet in thickness, and in places less than a foot, and consists of a thin layer of hard sandstone (ganister), and an impure sandy clay, but practically all the material is used for some purpose or other in the various kinds of brick. The sandstone is used for ganister and the clay mixed in with other clay for brick of low refractory power. In the other mines only the upper part of the clay, about 6 to 8 feet thick lying above the sandstone and called the upper soft clay, is worked. This is said to be a good quality of plastic clay and is used almost exclusively although there is another bed between this and the flint clay overlying and one or two beds said to occur at a lower horizon. One of these lower beds has been tested and found to be less refractory, hence has not been used but may be useful later in making vitrified brick.

The Bolivar clay is said to be not the best for certain grades of refractory ware where the heat is intense and continuous, so that some clay is imported from other points, some from South Fork and some from Blue Ball and Moshannon in Clearfield county and some ganister for the silica brick from Blair and Huntingdon county, but the bulk of the products is made from native clay. Almost every grade of brick can be made from it by the proper selection and mixing of the clays that comes from experience.

The Bolivar clay it is claimed will make a more porous and elastic brick than other clays that stand a higher heat, which makes them adapted to uses where they are subject to frequent and sudden changes of temperature, such as puddling furnaces, pottery kilns and coke ovens. The elasticity of the coke oven brick is certainly severely tried when they are heated to a high temperature and cooled by having cold water from the hose turned on them.

Dr. Stevenson in the Pennsylvania Survey report* 20 years ago, says of the Bolivar clay: "The Bolivar clay has a wide reputation and at one time the brick made from it were thought to be hardly inferior to those from the Mt. Savage region." He further says that the high prices previous to the panic of 1873 caused a carelessness in selecting the clay that almost ruined their reputation. If one may judge from the growth and prosperity of the works at the present time, they have regained their good reputation, as the bricks are not only sold in large quantities in the State, but are widely snipped to distant states and even to foreign countries.

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*J. J. Stevenson, 2d Pa. Survey Report KKK, 1877, p. 248.

Below we give the analyses of two of the clays used at Bolivar and one of the grades of fire brick.

Analyses of Bolivar Fire-clay and Brick.

	1	2	3
Silica, SiO^2,	43.46	63.81	53.08
Alumina, Al^2O^3,	41.61	26.39	43.41
Ferric oxide, Fe^2O^3,	1.03	1.23	2.44
Lime, CaO,	.24	trace.	.33
Magnesia, MgO,	.09	trace.	.18
Loss on ignition,	13.29	9.12	.26
Total,	99.72	100.55	99.70

No. 1. Flint fire-clay from South Fork, Cambria county.

No. 2. Westmoreland county flint fire-clay, King mine of Reese, Hammond & Co.

No. 3. The "Acme" fire brick made by Reese, Hammond & Co.

All the analyses were made in the chemical laboratory at State College.

Historical.—Bolivar is one of the oldest centers of the fire-clay industry in the State of Pennsylvania, and is said to be the second oldest in the United States, the Mt. Savage works, Maryland, being the oldest.

From all accounts James Glover was the pioneer in the industry. He came from the Mt. Savage works in Maryland about 1842 or '43, when he discovered the fire-clay at Bolivar, where he was engaged afterwards in the fire-clay business for more than 20 years, having associated with him several different partners in that time. However, the first bricks made at Bolivar were made by Mr. Glover and his family in a small factory operated by water-power on Tub Mill creek. He transported the brick to Pittsburgh by boat on the old Pennsylvania canal, which was then in operation. At Pittsburgh Mr. Glover himself went out soliciting orders for the brick and had great difficulty in selling them, but he managed to dispose of the boat load, and they proved to be of such good quality that the people who bought them soon began to inquire for the old Scotchman from whom they had purchased fire brick. Thus did Bolivar fire brick early acquire a reputation in the markets of the State.

Of the different partners that Mr. Glover had associated with him at Bolivar, Mr. Kier appeared to be the most active and Glover and Kier was the firm that is said to have done the largest business in fire brick during the first quarter century following 1843. Mr. Glover was at one time in partnership with Messrs. Baxter and Harley under the firm name of Glover, Baxter and Harley. Mr. Glover is said to have first started works near the mouth of Tub Mill creek, later at two different points up the creek. The site of one, the only one known, is shown on plate III. About 1862 he is said to have sold out his interests to Mr. Thomas Boyd and removed to Louisiana.

Mr. E. Robinson was early connected with the fire-clay interests at Bolivar. In 1857, in partnership with Mr. Benny he constructed the works near the depot at Bolivar, which he operated for several years, and which after being in the hands of several different parties were sold in 1867 to Reese, Hammond & Co., who still operate them. Mr. Robinson went to Black Lick, in Indiana county, where he constructed fire brick works, which he sold in a few years and returned to Bolivar, where he built the Enterprise Brick works, now owned by the Lincoln Fire Brick and Shape Co.

Reese, Hammond & Co.—One of the earlier pioneers in the brick industry, and probably one who has done more than any one else to make the Bolivar fire brick well known throughout the United States, is Mr. James Hammond, who came from Achonry, County Sligo, Ireland, to America in 1851, and after spending one year in eastern Pennsylvania, came to Bolivar in the spring of 1852 and secured employment with Mr. Glover in the fire-clay business, with whom he remained the greater part of the time until 1865, part of the time as mine foreman. When Robinson and Benny started their works in 1857, Mr. Hammond was Superintendent. In 1865 Mr. Hammond and his brother Thomas bought the Robinson works from Mr. Leibengood and others, and in 1867 took in as partners Isaac Reese and John McMath, forming the company of Reese, Hammond & Co., which has since become so widely known.

Shortly after the organization of the company in 1867 B. F. Reese succeeded Jno. McMath as a partner in the firm. Numerous changes have taken place since that time and Mr. James Hammond is now the only original member of the firm, which however has never changed its original name of Reese, Hammond & Co. The present personnel of the firm is James Hammond, T. M. Berkley, his son-in-law, T. R. Hammond, E. R. Hammond and J. B. Hammond, his three sons and B. F. Reese.

In 1872 they built an addition to their works which they call No. 3, and is so marked on the map. In 1881 they purchased a works that had been previously owned by Thomas Boyd, which now forms their works No. 1, located close to the railroad in Bolivar. In 1883 they purchased the old Glover works, which had been owned immediately preceding this by McCartney, Coulter and Dushane, thus gaining possession of what is probably the pioneer fire-brick works of western Pennsylvania.

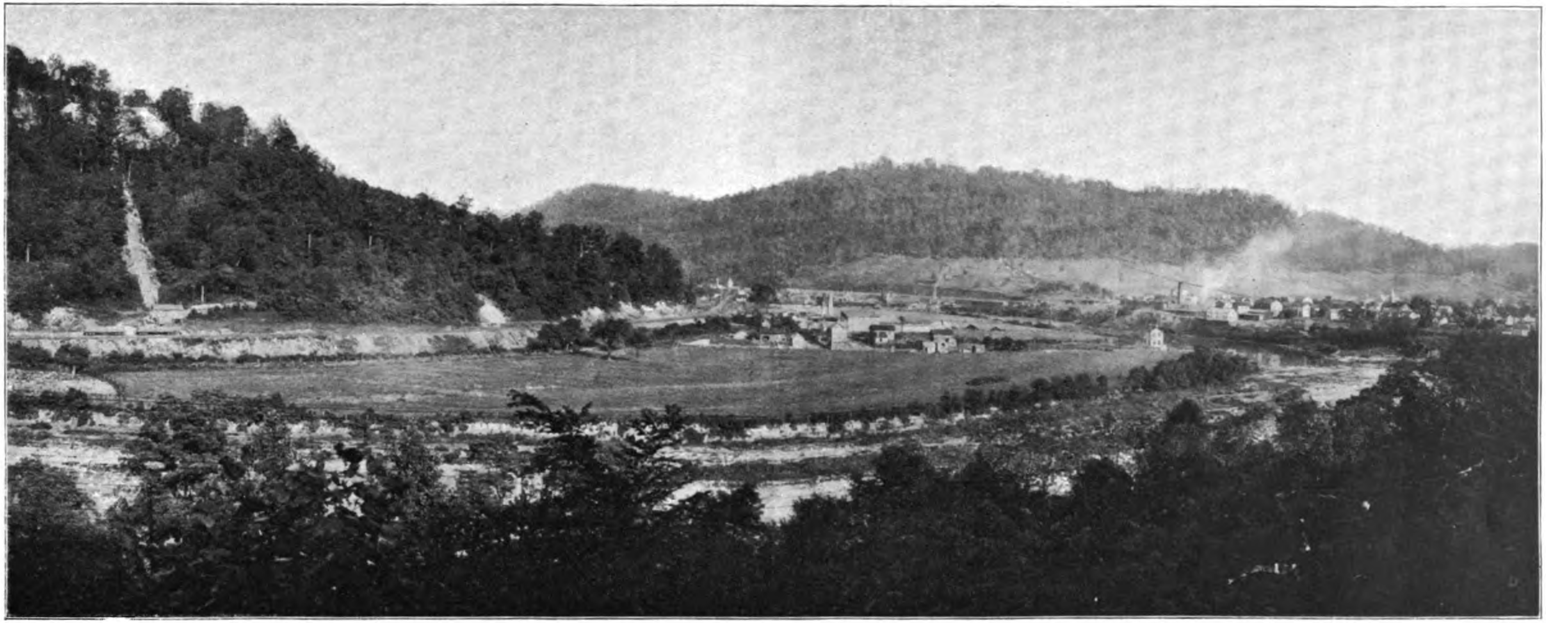

Fig. 21. View of Bolivar, Pa., looking up the Conemaugh Valley. The town is at the right. The first smoke at the right is R., H. & Co.'s fire-clay works, No. 1. The second smoke from the right marks their works No. 2 and 3. The buildings at the middle of view are the works of the Garfield Fire Clay Co. The white area in the upper left hand corner is the dump of R., H. & Co.'s flint-clay mine No. 4, from which the incline extends to the West Penn. R. R. The Penn. Central R. R. is concealed by the trees in the foreground, the telegraph wires showing at the lower left hand corner. R., H. & Co.'s new works, No. 4, constructed since this view was taken, are located on the open space to the left of the Garfield works. See Fig. —.

This company has apparently been prosperous and progressive from the start, having increased their annual capacity from 1,000,000 in 1867 to 10,000,000 in 1897.

They were obliged to wagon all their clay and coal from the mines to the works, distances varying from one-half mile to one and a half miles for 30 years. They recently secured possession of valuable clay deposits and frontage on the West Penn Railroad in Indiana county opposite Bolivar, and they now have all their clay transported by rail in individual cars at greatly reduced cost. In this year, 1897, they decided to branch out in a new line of brick-making and make vitrified paving and building brick, and they are now (Jan., 1898,) rapidly pushing to completion a new plant for that purpose which they call works No. 4, and which are located opposite Bolivar on the Indiana county side of the Conemaugh river. This promises to be one of the most conveniently situated and best equipped with modern machinery and appliances of the brick works in the State. The company has obtained clay from several different localities, and during the summer of 1897 they were operating six different mines, four of flint clay and two of soft clay, two in Westmoreland county and four in Indiana county. The largest opening, the one from which the largest quantity of material is obtained, is the one recently re-opened at the head of the incline above their new (No. 4) works. (See under clays, page 74). For certain classes of work they ship in clay from South Fork or Clearfield county.

They manufacture a great variety of refractory products, such as blast furnace linings, high grade furnace brick for open hearth steel furnaces, heating furnaces, soaking pits, and a complete line of rolling mill brick and shapes, also special shapes for Bessemer steel converters, for cupolas, brass furnaces, crucibles, potter's kilns and coke ovens; special shapes for locomotive arches, grate settings, stove linings and a general variety of shapes for any purpose where a high grade brick is required.

In the new works rapidly approaching completion they will manufacture vitrified paving brick and different kinds of building brick.

Their largest market is in western and central Pennsylvania, but they ship extensively to New York, New Jersey, New England, Ohio, West Virginia, Virginia, Alabama, Louisiana, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Montana, Washington, also to Canada, and have shipped to South America. The company has for many years shipped fire brick to Montana and Washington, but the freight rates across the continent are so heavy that the company is now meeting competition in Washington from English manufacturers. The present freight tariff is $15.00 per ton, about $52.50 per thousand on the brick. They find it cheaper to ship to New York and thence by ocean freight to Washington. They also ship from Bolivar ganister in a crude state that is used in Bessemer converters. They also ship crude fire-clay for the manufacture of gas retorts.

One of the improvements they aim to put in their new works now in process of erection is the blower system for drying the brick by utilizing the exhaust steam. The new works are located at the base of the hill below their largest clay mine and the force of gravity will be utilized in transporting the clay to the crusher and thence to the grinding pan. An automatic wire-cutting machine will be used and all the latest improvements known in the fire-brick industry. They are making the building fire-proof by using steel and brick construction. The advantageous position of these works is shown on the accompanying view, plate III.

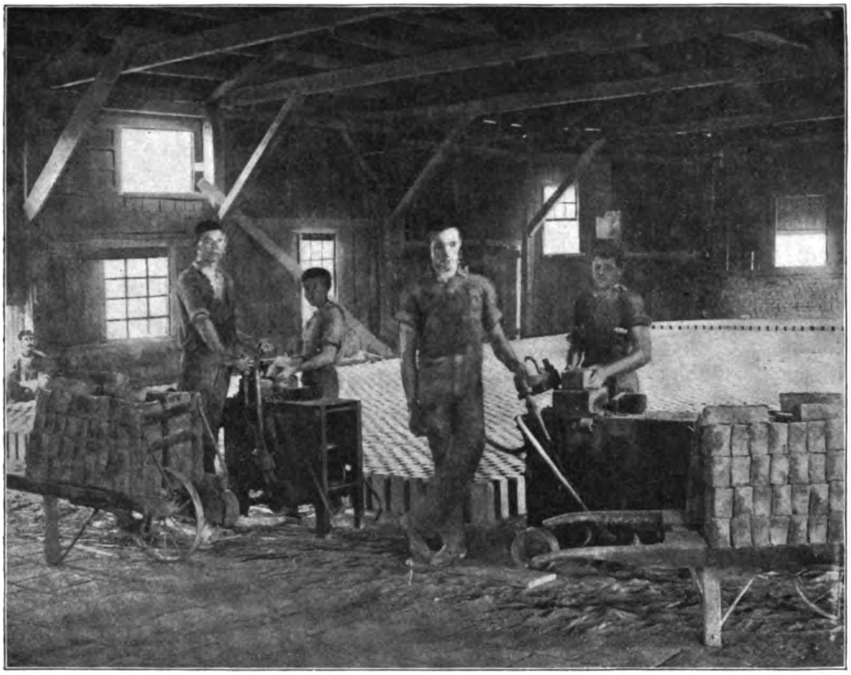

Fig. 22. Showing crew at work repressing hand-molded fire-bricks, Bolivar, Pa.

The Garfield Fire Clay Co., Bolivar, Pa.—The works of the Garfield Fire Clay Co. are situated on the north side of the Conemaugh river, in Indiana county, opposite Bolivar. They are connected by side track with the West Pennsylvania Railroad, over which, and the Pennsylvania Railroad, the products are shipped.

The works were started in 1889 by the Robinson Brothers, sons of the Mr. Robinson who started the works in 1857, now owned by

Reese, Hammond & Co., and who later, in 1872, started the works now owned by the Lincoln Fire Brick and Shape Co. The Garfield works are still in possession of the Robinson Brothers and have been in continuous operation since they started in 1889, except about a month of the present year (1897), when they were rebuilding the works after a disastrous fire. For two or three years the company was known as Geo. H. Anderson & Co., but Mr. Anderson soon withdrew and the old name was resumed. They are rebuilding on a slightly enlarged scale. The new building will have a floor space for 20,000 bricks per day.

They manufacture many kinds of fire brick and refractory material but their specialties are tiling for locomotives and stove linings. They ship locomotive tiling to many distant points, sending large quantities to the Chicago and Western Railroad for points west of Chicago. They ship tiling as far west as Oregon and east to Maine. They ship some to Cuba, Brazil and China. They have a three years' order for stove linings from one of the large stove works in Chicago.

They obtain the greater part of the clay from their own mines and get some for special work from Blue Ball, Clearfield county, and some from South Fork, further up the Conemaugh. They obtain their plastic clay from a drift at the works, which runs eastward under the railroad track into the hill. The property immediately adjoins that of the Lincoln Co., in fact the clay from both mines are brought to the surface through the same opening. (See plate III.) The clay is only a few hundred yards southeast of the mine of Reese, Hammond & Co., and is the same bed geologically, although it here lies much lower in the hill than in the other mine, owing to the southeast dip of the strata.

The flint clay mine of the Garfield Co. lies about a mile east of their works, which distance the clay is hauled in wagons. It is the Bolivar clay, the same bed geologically as that at the other mines. This mine is said to be the oldest in this vicinity.

Lincoln Fire Brick and Shape Co.—The works of the Lincoln Fire Brick and Shape Co. are situated on the south side of the Conemaugh river and the Pennsylvania Railroad, about half a mile above the Bolivar station (see plate III). The works were established by Mr. E. Robinson, in 1872, and have since been operated by the Enterprise Manufacturing Co., the Bolivar Brick Co., and the present owners, the Lincoln Fire Brick and Shape Co. They are idle at present and have been nearly all this year up to the present time (August, 1897).

They manufactured fire brick and refractory ware of different kinds from clay obtained from their own mines near the works. They obtain the plastic clay from a drift in the hill immediately back of the works, at a level a little above the works. The flint clay is obtained at an elevation of a hundred feet or more above the works and nearly half a mile distant. The clay is run out on trucks and hauled on a tramway to the head of an incline at the works where it is run on the incline to the crusher. The flint clay (Bolivar) is 18 to 20 feet thick and presents a nice appearance as exposed in the mine. There is in places diffused iron oxide, so that some care is needed in selecting the clay. The upper part of the bed, six to eight feet thick, is very dark colored, the "black clay," and is considered the most valuable part of the deposit. In some places only the upper black clay is worked, the lower, lighter colored, less valuable clay, being left for a more convenient season.

The Lincoln Company has an experimental coke plant at the brick works, in which the aim is to save the by-products. It is also idle.

David Coulter's clay mines.—David Coulter, who resides in Bolivar, has been mining and shipping fire-clay from the vicinity of Bolivar for many years. He is at present operating two mines in Indiana county, nearly two miles northeast of Bolivar, on the north side of the ridge from the other clay mines. (See plate III for location.)

He has been mining the soft or plastic clay about ten years, working a thickness of five or six feet, corresponding to the upper one of the two beds worked by Reese, Hammond & Co., on the south side of the hill. The flint clay, about 250 feet above the plastic clay, is the Bolivar clay. He works only five to eight feet of the upper part of the bed, which he thinks is a superior quality for gas retorts, for which it is used.

There is an incline from both the soft clay and the flint clay to the tramway at the foot of the hill, which runs down the Roaring run hollow to the side track on the West Pennsylvania Railroad on the bank of the Conemaugh river. All his clay is shipped to James Gardner, Jr., Lockport, where it is used in making gas retorts.

Mr. Coulter formerly operated a clay mine on the south side of the hill, about half a mile south of his present mine.

The Lynn clay mines, designated on the accompanying map (plate III), were not visited by the writer. They now belong to Reese, Hammond & Co., and are not operated because the cost of transportation to the works is too great.

Jas. Gardner, Jr., Lockport, Pa.—The fire-clay works of Jas. Gardner, Jr., are located on the south side of the Conemaugh river between the river and the Pennsylvania railroad at Lockport station, two miles above Bolivar, and have been in operation since 1863. Besides the ordinary gas retort they make special retorts for iron and steel mills, and have recently shipped some special forms to a gold mining company in Georgia. Their chief trade, however, is in gas retorts, which are shipped to all parts of the United States. In the manufacture of fire-clay gas retorts they have no rival in Western Pennsylvania. The gas retorts vary in size, some of the larger ones made at Lockport weighing about 2,100 pounds, and standing 15 to 18 feet high. Some are made by hand, a process of several weeks duration, and some are made by machinery. Mr. Gardner has invented much of his own machinery, not simply for molding and building up the retorts, but also for handling them both in the green state and the burned finished product, in putting in and removing from the kilns and loading aboard the cars. He has also an ingenious contrivance for weighing the clay before mixing.

While gas retorts form the bulk of the product, fire bricks and other refractory materials are made in small quantities.

Mr. Gardner obtains some of his clay from Mr. David Coulter at Bolivar, some from South Fork up the Conemaugh and some from Clearfield county. Formerly clay was mined in the hills near the works, but it is now said to be more profitable to buy the clay from other points than to mine it at Lockport.

A commendable feature that a visitor notices in Mr. Gardner's works is the neatness and cleanliness about the buildings and the yard, such a striking contrast to the average brick yard.

A. J. Haws & Son, Johnstown, Pa.—The works of A. J. Haws & Son were started in 1859 by Mr. A. J. Haws, and have been under his management ever since with the aid of his son H. Y. Haws, who became a member of the firm about 1879. The company claims a yearly capacity of 15,000,000 bricks, including 500,000 or more silica brick. Including the men in their coal mines they employ about 400 men. It thus ranks among the larger and older fire brick works in the State.

They make a specialty of blast furnace linings, but manufacture all kinds of fire brick, silica brick, tuyeres, and brick converter bottoms for Bessemer steel works, and nozzles, stopper rod sleeves and runner brick for bottom casts.

The flint clay for the refractory ware they obtain at their mine near South Fork station, on the Pennsylvania Central railroad; the plastic clay comes from a bed about four feet thick that lies 110 feet beneath the works. It is mined along with the accompanying coal (the Miller coal) and elevated through a shaft at the works. The ganister or silica for their silica brick is obtained from Blair and Huntingdon counties.

M. L. Williams & Co., Johnstown, Pa.—M. L. Williams started a fire brick works at Coopersdale on the north side of the Conemaugh river about two miles below Johnstown in 1889. He operated it alone for a number of years, but a few years ago took in a partner, making it M. L. Williams & Co., since which time the works have been enlarging their capacity.

They manufacture only high grade refractory material, mostly specialties for steel works. There is an air of secrecy about the works, visitors not being admitted. Some of the processes are said to be patented and others kept secret and carefully guarded.

Some of the clay is obtained from the mines on South Fork, but the greater part of it is said to come from the mines at the works. It is said to be a semi-plastic clay about two feet thick mined along with the overlying coal, the "four-foot bed" which is about three feet and eight inches thick.

Hiram Swank's Sons, Johnstown, Pa.—Mr. Hiram Swank established a fire brick works in what is now the 6th ward of Johnstown as long ago as 1856, which were in operation until about six years ago, when new works were constructed in the 10th ward on the line of the Penn. Central R. R. This is on the opposite side of the town from the other companies mentioned. The business is now managed by Hiram Swank's sons, Chas M., Albert F. and Milton R. Swank. They manufacture centre and bottom plate runner brick, sleeves, nozzles and Bessemer tuyeres, also vitrified buff-colored building and paving brick.

They operate a clay mine about half a mile east of the works and ship some of their clay from South Fork Station, a few miles further up the valley.

THE YOUGHIOGHENY VALLEY.

It will be seen on consulting the map (plate I) that there is a large number of fire brick works in the Youghiogheny valley. There is also quite a variety in the character of the products. As it includes the extensive Connellsville coke region, the manufacture of coke-oven brick is naturally an important feature. Four of the works manufacture silica brick and one makes basic brick.

Layton Station.—Layton Station on the B. & O. R. R., below Connellsville is quite a center for refractory ware as there are three companies in active operation, one works idle, and another idle factory but two miles distant. There is also a fire-clay mine that ships clay to Pittsburg for the manufacture of glass pots.

The Layton Fire Clay Co. operates the first fire-clay works met in ascending the Youghiogheny river. The works are on the B. & O. R. R., on the east side of the river, about half a mile below the railway station. The main office is in McKeesport, Bowman Bros. forming the company. These works have been operated by the present company for six or seven years and for a number of years previously by other companies. They have a capacity of 30,000 bricks per day, and manufacture fire brick, buff building brick and paving brick.

The fire bricks are made by hand and the building and paving bricks are made by machine, the Freese auger machine being the one used. Most of the bricks are shipped to points along the B. & O. R. R., in the Youghiogheny and Monongahela valleys, a few being shipped on the P. & L. E. R. R.

The fire-clay is obtained from a bed in the hill about 50 feet above the works, where drifts are run into the bed and the clay run out on cars and dumped at the works. Both hard and soft clay come from the same opening, the relative proportion of the two varying in different parts of the bed. The hard clay overlies the soft and at the mouth of the drift is from one to two feet thick and varies but little for the first 50 feet from the outcrop, after which it thickens, and at 100 feet from the outcrop it is four or five feet thick, and is said to increase further in the hill to eight or twelve feet, but runs quite irregularly in thickness. The entire bed, both soft and hard varies from six to twenty feet in thickness. The clay is overlain by a heavy bed of sandstone and underlain by a shaly sandstone. The adjacent strata as exposed on the west bank of the river opposite the works show as follows:

Section at Layton Station.

	Feet.
Heavy bedded sandstone suitable for building stone, ...	30
Sandy shale, ...	8
Sandstone heavy bedded, ...	6 to 8
Fire clay, hard and soft, ...	12
Thin bedded sandstone, ...	5
Shaly sandstone and shale, ...	25

The soft clay contains a few iron balls but none have been found in the flint clay.

About 50 feet above the fire-clay on the hill is a bed of blue clay said to be from six to eight feet thick, which is used by the company for making building and paving brick. It will vitrify at a much lower temperature than the fire-clay.

The Stuart Fire Brick Co's works are situated at Child's Station, on the Pittsburgh and Lake Erie Railroad, on the west side of the Youghiogheny river, about half a mile above Layton station. The works were started in the spring of 1893, by Mr. William Stuart, who later opened the works just across the river, now owned by the Silica Brick Co., and the same person who still more recently opened and now operates the brick works at Kingston, near Ligonier. The Pittsburgh office of the present company is in the Conestoga building.

They make silica and sand brick only. The silica is quarried about half a mile from the works and run in on a tramway. It is said that there was a sand works at one time near the site of the brick works that used all the suitable silica near the works. The company claims to have two beds of soft fire-clay on their property, one about five or six feet thick, the other about eight feet. Both have been opened but not used in any quantity.

Silica Brick Co., Limited, is the name of the company that owns the works on the east side of the river opposite the works of the Stuart Company and about half a mile above the Layton station on the B. & O. R. R. They are not in operation at present (August 1897) and but little information could be obtained regarding them. The works are said to have been started but a year or two ago and stopped for want of orders.

They advertise all kinds of fire brick, shapes and tiles, also Pompeian and buff building brick. There are three kilns now standing full of silica brick. The silica and soft fire-clay are obtained on the company's property adjoining the works.

Mrs. M. J. Wurm has been shipping fire clay since 1887 from her mine on the hill about a mile east of Layton. It is a superior quality of clay for glass pots and is said to be shipped for that purpose to Pittsburgh. The clay has been mined on a small scale and shipped at the rate of a few carloads per year. The bed is said to be from four to six feet in thickness. The pot clay is carefully selected by hand from the run of the mine and the remainder is used for common fire brick.

The analysis of this glass-pot clay shows its purity and adaptability for the purpose. It will be noticed that the total fluxing constituents are less than two per cent.

Analysis of glass-pot clay from Layton Station.

	Per cent.
Loss on ignition (water, CO^2, etc.),	9.29
Silica, SiO^2,	64.89
Ferric oxide, Fe^2O^3,	0.29
Ferrous oxide FeO,	0.21
Alumina, Al^2O^3,	24.08
Lime CaO,	0.41
Magnesia, MgO,	0.19
Potash, K^2O,	0.87
Soda, Na^2O,	0.16
Total,	100.39
Kaolin base,	59.11
Free silica,	36.75
Total fluxing constituents,	1.83

Other mines have been opened in the vicinity of Layton for fire-clay, but none of them are in operation at present.

Lavenia Station.—The Crescent Fire Brick Co. formerly operated a brick works at Lavenia Station, on the Baltimore and Ohio Railroad, about two miles above Layton. The works are now idle with no one in charge. The machinery has not been removed and is rusting badly. It could not be ascertained how long they operated or how long they have been idle. They are now advertised for sale by the Fidelity and Trust Company, Pittsburgh, Pa.

The clay was obtained from two openings, one about 50 feet, the other about 100 feet above the works. The lower opening is in a bed 10 to 12 feet thick, of semi-plastic clay, called flint clay, that is overlain successively by six inches of coal, 20 inches of shale and clay, two feet of coal and a heavy bed of sandstone. The upper bed of clay is seven or eight feet thick at the outcrop and is soft, plastic clay overlain by 30 inches of coal, three feet of sandstone and a heavy bed of black fissile shale. No tests were made of the quality of the clay, but the appearance at the outcrop suggests clay of good quality for buff building and paving brick or low grade refractory brick.

Connellsville, Jos. Soisson & Co.—Jos. Soisson & Co., of Connellsville, is one of the oldest fire brick companies in the State. Mr. Jos. Soisson, the senior member of the firm, operated fire brick works at Portage, No. 8, on the line of the old Pennsylvania canal, from 1859 to 1862. In 1862 the canal passed into the possession of the Pennsylvania Railroad and the brick works stopped at that point.

The company now operates three large works in the immediate vicinity of Connellsville, known as (1) the Volcano, (2) Davidson, and (3) Moyer works.

Jos. Soisson & Sons also operated works at Rankin Station from 1889 to 1893, under the name of the Crescent Fire Brick Co., where they made silica and other bricks. The works were destroyed by fire in 1893, and were not rebuilt. In the three factories now operated by this company they manufacture different grades of refractory brick, building brick and paving brick. Much of the brick pavement in Connellsville was furnished by them.

The Volcano, the oldest of the factories at present operated by the company, was started in 1864, and is situated on the east side of the Youghiogheny river, a short distance south of Connellsville, on the Baltimore and Ohio Railroad. They manufacture fire brick, building brick and paving brick.

The fire-clay used in the Volcano works comes from the company's mines at Bailey's Point, several miles up the Youghiogheny river from Connellsville. Formerly they obtained all their fire-clay from their mines a half mile or more east of the works on the west slope of Chestnut Ridge. These mines were operated until last winter (1896), when they were abandoned for the more productive ones at Bailey's Point. The debris has fallen into the old mines, concealing the clay so that little can be said of it at present from observation. It is in the lower coal measures immediately underlying the "four-foot" bed of coal which is here between three and four feet thick. So far as can be judged from the partial opening, the clay bed may vary from 10 to 15 feet in thickness. The analyses of this clay would indicate a highly refractory one, and evidently the only reason for abandoning the mine must have been cost of mining. However, the analysis is not complete and the value of the clay might be greatly changed by the missing eleven per cent.

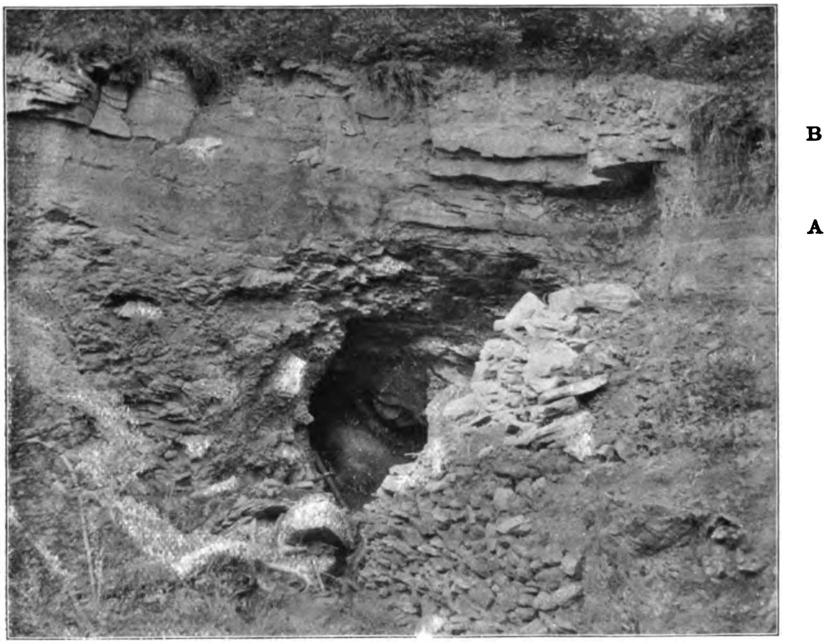

Fig. 23. View in the lower flint fire-clay mine at Moyer, Pa. A, is a coal seam about 4 feet thick. B, sandstone overlying the coal. All below the coal is fire-clay, 10 to 12 feet thick.

Analysis of fire-clay, Jos. Soisson & Co., Connellsville, Pa.

	Per cent.
Silica SiO^2,	55.38
Alumina Al^2O^3,	30.42
Iron Fe^2O^3,	trace
Lime CaO,	.52
Magnesia MgO,	.34
Alkalies K^2O, Na^2O,	.22
Water H^2O,	1.70
Total,	88.58

The materials for the paving and building brick are obtained from the clay and shale bank at the Volcano works, which consists of a bed of clay and shale about 25 feet or more in thickness overlain by two to four feet of terrace deposit, consisting of sand and boulders.

The paving brick and building brick are made by machinery, and the fire bricks are molded by hand. The experience of this company is that the hand-made fire bricks give better satisfaction than the machine-made ones.

The tests made by the Connellsville city engineer, Mr. Samuel Foutz, show the Volcano paving bricks to compare favorably with those from many other well known localities, so favorably that they were recommended for use on the Connellsville streets.

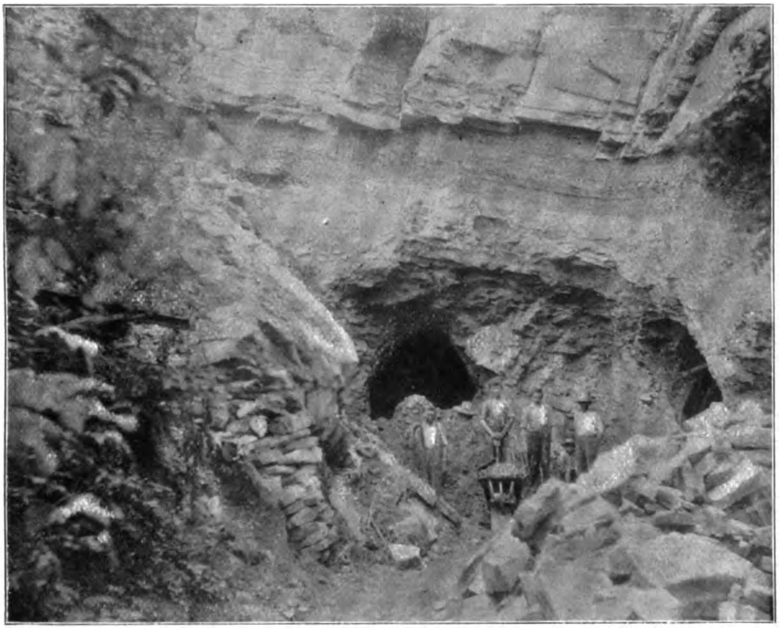

Fig. 24. View in the upper flint clay mine, near Moyer, Pa. B, sandstone; A, Upper Freeport coal. All below A, flint fire-clay (Bolivar clay).

Davidson Works.—The Davidson brick works of Jos. Soisson & Co. are about one mile north of Connellsville between the B. & O. and the Southwest Pennsylvania railroad tracks. The chief object of locating the works here was to get the advantage of shipping over both the railways. This is the newest of the three works, having been founded in 1878. Fire bricks only are manufactured at the Davidson works, the clay for which is obtained from different points, mostly from their mine at Bailey Point. The bricks are hand-molded, and pressed in hand-press when partly dry.

Moyer Works.—The Moyer Works of Jos. Soisson & Co. are situated on the east side of the Southwest Pennsylvania Railway, about 200 yards south of the Moyer station. The works were started in 1871 and have five kilns in active operation making fire brick only. They use the fire-clay from their mines about two and a half miles east of the works along with some blue clay hauled by wagon from south of Connellsville. They have used some clay and shale from the creek bank near the works but are not using any of it at present. It has presumably been used in the manufacture of building or paving brick, which are not being manufactured at present. The products of these works are shipped over the Southwest Pennsylvania Railroad.

The clay used at the Moyer works comes from the west slope of Chestnut ridge about two and a half miles east of Moyer. It belongs beneath the Freeport coal near the top of the lower productive coal measures at the same horizon as the flint clay at Bolivar. It resembles the Bolivar clay in appearance. A section across the clay bed shows:

	Feet.
Thin bedded shelly sandstone,	12
Coal, Upper Freeport (E),	4
Shale ("Soapstone"),	3 to 4
Flint clay, Bolivar,	10 to 15
Plastic clay mined in only a few places,	3

The coal is not mined except in small quantities. The flint clay, as in nearly all other localities where it is mined, contains numerous iron ore concretions, "ore balls," making it necessary to hand pick it. If properly picked it furnishes a good highly refractory clay. It has a dark-gray color, and splintery to conchoidal fracture.

The clay is mined at present in two openings on the hillside south of the valley. See figures 23 and 24. The clay has been mined here more than a quarter of a century, and that large quantities have been removed is evidenced by the numerous abandoned openings on the hillsides. There are at present, August, 1897, four teams hauling clay from these mines to the works at Moyer.

Bailey Point clay mine.—Jos. Soisson & Co. obtain most of the refractory clay for their Volcano and Davidson works from their mines at Bailey Point on the east side of the Youghiogheny river about eight miles above Connellsville and about half a mile below Bear Creek station on the B. & O. R. R. The mines are near the top of the river hill, about 300 feet above the railroad. There is an incline railway from the level of the mines to the railway side track and a tramway along the bench of the ridge connecting the different openings with the head of the incline. They ship clay from here at the rate of about two cars per day.

The bed of flint clay is 12 to 15 feet thick overlain in places by two to four feet of soft clay and 10 to 18 inches of soft coal. The clay is underlain by a coarse grained sandstone, and is mined entirely from the surface by following the outcrop along the face of the hill, working it back into the hill until the overburden becomes too heavy to remove with profit. It belongs to the same geological horizon as the Bolivar flint clay, that is just underneath the Upper Freeport or E bed of coal near the top of the lower productive coal measures. One of the seven Soisson sons is in charge of the clay mines. Some years ago clay in considerable quantities was mined from a lower bed, nearly half a mile further north and about 200 feet lower on the hillside. The lower mines have been abandoned for a number of years.

Stewarton. -There is an abandoned fire brick works at Stewarton station on the B. & O. R. R., about six miles above Connellsville that was said to have been operated about two and a half years ten years ago by Houston, Tigert and other of Connellsville. No further particulars could be learned concerning it.

Near the top of the hill about half a mile below Stewarton is a fire-clay mine that has been operated for about 20 years. The mine was opened, it is said, by Mr. John Harbaugh about 20 years ago, and has been operated by different parties since that time. Mr. Paul obtained possession of it this year (1897) and is preparing to work it more vigorously than it has been worked for several years. The clay varies greatly in thickness, in most places being about eight to ten feet, but sometimes thinning to a foot or less. Both flint and plastic clay occur together, sometimes one predominating, sometimes the other. It is overlain by about two feet of soft coal and an indefinite thickness of soft, fissile, brown shale. The clay has been worked by benching along the outcrop on the hillside for a half mile or more, being worked back until the stripping becomes too heavy for removal with profit, which in most places is 15 to 18 feet. A tramway runs along the face of the mine on which the clay is transferred to the head of the incline where it is run down by gravity to the side track on the B. & O. R. R. It is shipped to the fire-brick yard of the McClure Coke Company, at Lemont furnace.

Ohio Pyle.—Messrs. Kennedy and McFarland have mined fire-clay in a small way at several places in the vicinity of Ohio Pyle. At present (August, 1897), they are opening a clay mine near the top of the river hill on the Abram Skinner farm nearly two miles north of Ohio Pyle village. It appears to be the Bolivar clay lying about 15 or 20 feet below the Freeport coal. The present opening which is on the outcrop, shows about eight feet of flint clay, but does not penetrate to the bottom so that the entire thickness of the bed is not shown.

A small quantity of clay was mined at one time in the neck of land near the falls. Clay has also been mined from two openings a few hundred yards above the village, on the east side of the river; in one opening it is said to be about nine feet thick, in the other about three feet, showing the thickness of the bed to be quite variable. It is probably about the horizon of the Clarion coal. There is an outcrop of fire-clay on the roadside at the Ohio Pyle House that is probably the same horizon as that in the last mentioned openings. Clay has also been mined and shipped from openings along Cucumber run near the falls. It is possible that some of these deposits will be more extensively operated in the future.

Near Connellsville.—On the hill on the west side of the Youghiogheny river about a mile and a half above Connellsville, there are several beds of fire-clay exposed. An opening was made into one of these deposits near the Frick Company's water works by Mr. Kennedy and others for the Dunbar Fire Brick Co. This clay appears to be of good quality, as shown in the drift which has been driven into the bed 30 or 40 yards. The bed is from four to six feet thick. It has been temporarily abandoned because of difficulty with the water company in obtaining a way for a side track from the mine to the railway. The clay is on the property of Mr. Washington Hurd.

Dunbar, Pa.—The Dunbar Fire Brick Co. operates a fire brick works at Pechin station about half a mile southwest of Dunbar Station, between Connellsville and Unionville, located close to the Southwest Pennsylvania Railroad and has sidetrack to both this road and the B. & O. R. R.

They have a capacity of 20,000 bricks per day and make coke oven brick, mill, paving and building brick, but the largest trade is in coke oven brick, which they ship to various points in the coke region of Pennsylvania and West Virginia. They make a patent paving brick with a guttered top about one-third larger than the average sized brick, that appears to be meeting with some favor in the market. They make the Pompeian and other fashionable shaped buff-colored building brick.

The Dunbar Company obtains nearly all its clay from their mines, about two miles from the works, and about a mile southeast of Ferguson station, from which there is a tramway to two of the mines—the plastic clay. The flint clay is obtained from openings higher on the hill from which the clay is hauled in wagons to the tramway. The flint clay is obtained from two different beds; the upper bed, which is worked but very little, contains a thickness of only two or three feet of clay, and while it is of good quality, the bed is too thin to work with profit. The under bed which outcrops and is worked at a higher level on the hill, reaches a thickness of 14 feet in places, but it varies at close intervals, often a few yards, from a thickness of 14 feet to four or five feet. Both beds are said to furnish a highly refractory clay.

Mt. Braddock.—At Mt. Braddock station about two miles southwest of Dunbar, are the Eureka Fire Brick Works, which have been operated by this company for 14 years. Previous to that time they were managed by a company known as the Mt. Braddock Fire Brick Co. They have a capacity of 12,000 bricks per day and manufacture coke oven, building and paving brick; the largest trade being in coke oven brick, their markets being mostly in the coke regions of southwest Pennsylvania.

The flint clay for the Mt. Braddock works comes from the hill about a mile and a quarter east of south of the works. The bed varies from four to six feet in thickness, sometimes a little less than four feet, and lies immediately underneath a heavy bed of sandstone. The clay has been mined from three different openings over an area of several acres. The one in which they are now working has been opened about two years and has undermined an acre or more. The clay contains some iron ore on the outcrop, but a short distance from the outcrop the iron almost entirely disappears and the clay is light colored and quite hard. It is taken by tramway to the works.

The plastic clay used by the Eureka Company comes from the mountain nearly two miles further south where it is said to occur in a bed about six feet thick. It is transported part of the distance by wagon and part by tramway.

Lemont Furnace (*Darent Station, Southwest Pennsylvania Railroad.*)—The McClure Coke Co. have operated a fire-brick works at Lemont Furnace for 25 years. They make coke-oven brick exclusively, but by no means enough to build and keep in repair all their numerous ovens. The capacity of their works has been recently enlarged from 6,000 to 9,000 bricks per day.

They obtain some clay from the mines at Stewarton on the Youghiogheny river, but the greater part of it comes from the hill about a mile southeast of the works. The clay is mined from a great many different openings on the hillside. The clay bed dips at about the same angle as the slope of the hill, so that while it does not outcrop it is in most places near the surface. It is quite irregular in thickness, varying in short distance from two to twelve feet or more. There is generally a foot or more of soft clay on top of the flint clay which in places almost entirely replaces the flint clay. The clay contains considerable iron ore.

White House (*Wymp's Gap Postoffice*).—D. H. Emme has mined fireclay near White House (formerly called White Horse), in Fayette county, since 1868, but has only been shipping clay regularly for the last 12 years. At first the clay was hauled to the Monongahela river and shipped by boat. After the railroad was built he shipped from Fairchance, later from Smithfield, and now from Outcrop Station on the Baltimore and Ohio Railroad, about two and a half miles from the mines. The clay is used for making glass pots and is said to be of superior quality for that purpose. The Pittsburgh Clay Pot Co., in Allegheny, probably the largest clay pot works in this country, use the clay from these mines. They state that it is better adapted to their purpose than any other clay they get in this State, and that they could use more of it if they could get it. The clay is obtained from open pits as the roof is too uncertain for it to be mined under cover. It occurs in a bed 12 to 15 feet thick, overlain by clay and coal. The following analysis shows it to be a clay of remarkable purity.

*Analysis of glass-pot clay from Wymp's Gap, Pa.**

	Per cent.
Loss on ignition,	11.94
Alumina Al^2O^3,	32.80
Silica SiO^2,	54.23
Oxide of iron,	0.21
Total,	99.18

Section in one of the openings at Emme's pot-clay mine, White House, Pa.

Soil, 5 feet.
Coal, with some shale, 4 feet.
Soft shale, 1.5 feet.
Hard shale, 4 feet.
Coal, 3 feet.
Blue clay with shale and iron stains, 10 feet.
Flint clay (pot clay), 10 to 15 feet.

The upper coal bed is said to be seven feet thick in places but is very slaty. The lower bed, known locally as the Kirk coal, has been mined for local use. The flint clay is a hard, clean looking, light gray colored clay, containing considerable iron on the outcrop.

IN THE MONONGAHELA VALLEY.

Fire brick works were found in only two places in the Monongahela river valley, viz: Manown and Courtney, at both of which places the material used is the gob from the coal mines. This is the "horse back" or clay parting that occurs in the Pittsburgh coal seam and is removed in the mining of the coal. The clay is about six to ten inches in thickness and while it would not be profitable to mine this clay alone, since it is removed as waste material along with the coal, it ought to be worked with profit.

For the best grade ware the clay is selected as it comes from the mine, but in some of it all the gob, including the shale and other waste along with the clay is used. One might think that the clay from a seam six to ten inches thick would not supply much material for clay works, but some of these mines have been in operation many years and have undermined hundreds of acres of coal, and a seam of clay six inches thick spread over a hundred acres or more means a large quantity of clay.

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*Made for The School of Mines in the Chemical Laboratory of The Pennsylvania State College.

The persistence of this clay seam throughout the entire area of the Pittsburgh coal bed is truly surprising. Over thousands of square miles this clay seam runs nearly uniform in thickness. What seems even more surprising is the same remarkable persistency of thin seams one-fourth to one-eighth of an inch in thickness. It is a wonder that more of this clay has not been utilized either for fire, building or paving brick, as there are vast quantities of it piled around the numerous mines over southwestern Pennsylvania.

Courtney.—John Tempest & Co. operate the fire-clay works at Courtney Station, on the Monongahela division of the Pennsylvania Railroad, about two miles below Monongahela City. The works are situated on the river bank near the station, and they use the gob or clay from the mine of the Mingo Gas Coal Co., the dump being close by the works. Mr. John Tempest is said to have started this industry of using the gob from the coal mine and invented his own machinery for handling and working the material. He says the machinery in the other works at Manown is modeled after his. They began operations at Courtney seven years ago and have had a prosperous business ever since. They operate eight kilns and have a capacity of 5,000 bricks or shapes per day. While they make some fire brick their principal trade is in sleeves, nozzles and steel runners for the large steel works. This use of fire-clay while newer than the brick industry is a large and rapidly increasing one, and this coal mine clay appears to be well adapted to the requirements of the steel trade. The principle markets are Pittsburgh and vicinity, Youngstown, Ohio, and eastern points.

They clay is worked much like other fire-clay. It is ground in dry pans, screened and mixed in the pug mill. The short pipes for steel runners are made differently from the somewhat similar looking draintile. Instead of coming from the machine in a continuous hollow tube and being cut by wires into proper lengths as with the tiling, it comes from the machine in a continuous solid clay bar about the diameter of the pipe. A piece about the right length is cut off by hand and fed by hand into a die in another machine, where it is stamped by a descending piston. As the piston rises the stamped piece is deftly removed by a workman and another piece of clay inserted, so that the process is a comparatively rapid one. The side hole in the pipe is cut by hand with a piece of tin spout thrust through a hole in a wooden form which fits over the pipe.

Watson Station (near Manown).—The Tempest Fire Brick Co. operates the works at Watson Station on the Pittsburgh, McKeesport and Youghiogheny Railroad, a short distance above Manown. The works were started about five years ago by the Watson Mine and Manufacturing Co., with Mr. Tempest, of Courtney, as manager. Later Mr. Laughlin superseded Mr. Tempest as manager. The works have been closed since about the first of this year (1897), and now (August) they expect to reopen in a few days as the Tempest Fire Brick Co., with Mr. John Tempest again in charge. They have 14 kilns and a capacity of 10,000 brick or shapes per day. They use the horseback clay or gob from the coal mine. As at Courtney, the principal trade is in steel runners, shapes and nozzles for the steel works, but fire bricks are made on demand.

Manown, Pa.—The Manown Manufacturing Co. (main office Lewis Block, Pittsburgh), operate a fire brick works at Manown, on the east side of the Monongahela river, about two miles above Monongahela City. Mr. Jenkins is the superintendent. They have been in operation two years and, like the Watson and Courtney works, the chief trade is in pipe shapes for open hearth and Bessemer steel works. They also make fire brick and ground fire-clay. They have eight kilns and a capacity of from 2,000 to 5,000 shapes per day, depending on the size. They use the clay from the parting in the Pittsburgh coal bed as it comes from the dump of the Youghiogheny Coal and Gas Co. The clay seam is about eight inches thick, but as the mine has been in operation many years, there is a large supply of it on hand.

They ship a great many pipe shapes for the steel works to Alabama, but their principal trade is in Pennsylvania and Ohio.

CHAPTER VI.

RED AND BUFF BUILDING BRICK.

- Building brick clays.
    - Composition.
    - Physical properties.
    - Varieties.
- Shales.
- Classification of building brick.
- Buff brick.
- Spotted brick.
- Vitrified brick for building.
- Machinery and methods for making brick.
- Paving brick.

As the brick clays are so widely distributed, so common, so well known, and the price of the brick so low, the value and extent of the common brick industry is frequently overlooked particularly by the manufacturers of the high priced stock. Despite the little attention that is given to the subject the aggregate value of the red bricks produced is greater than that of any other single clay product in the State or in the United States, and it will no doubt continue so because of the great numbers of producers and the vast quantities produced. It is likewise an industry that should be encouraged as the use of bricks in place of wood is to be commended in the towns from the standpoint of safety if not of architectural beauty. From the latter standpoint brick, especially common red brick, are inferior to first class stone and in the finer and more expensive structures they can not hope to compete with the stone, but in the cheaper business houses and dwellings they can be and are used extensively, while the buff and variegated bricks and the finer grades of red brick and terra cotta are coming into very active competition with stone in the most expensive buildings.

Building-brick clays and shales.—The clays used in making building brick have an exceedingly wide range in composition, color, texture and origin. Those used in making the buff or light colored bricks come under the general term fire-clays. Red-brick clays are widely distributed and occur as alluvial deposits along the streams, or as soils from decayed shales, limestones, sandstones or other rock, or from a mixture of two or more of these. In certain localities the clays may be a glacial deposit, and in some localities loess. In the region covered in this report, only the first two classes are used if we include in the alluvial deposits the terrace clays used so abundantly about Pittsburgh and elsewhere along the rivers. In recent years shales of different kinds have been used extensively for making building brick. The use of shale probably began in the manufacture of paving brick and from that extended to the building brick industry.

So many grades and kinds of material are used for making brick that it is sometimes thought that anything which has sufficient plasticity to be molded will do, which in part is true. Almost any soil or rock that one can find, except the nearly pure sand, can be molded and burnt into brick, but it is not true that they will all make equally good bricks, in fact many will make quite inferior bricks and many have been used for this purpose which should not have been used. Some of the necessary conditions for good brick clay are:

1. Proper Composition.—While good brick material may have a wide range in composition it is not indefinite by any means. It should not be too rich or fat, that is the percentage of alumina should not be too great or the shrinkage will be excessive, and the brick will crack and craze in the drying and burning. The extremes are given in the table below by Wheeler. This defect may be and often is remedied by mixing sand or other material with the clay. Sand is the chief

foreign constituent in the clay and ranges from 20 to 60 per cent. It prevents cracking and excess shrinkage. If not in sufficient quantities naturally it can be added artificially in the grinding and mixing of the material.

The alkalies, lime, iron and magnesia are the fluxing constituents, but in red brick may have a wide range if proper precautions are used in burning. If red bricks are desired there must be a sufficient amount of iron present, not less than two or three per cent., but the percentage allowable depends partly on the manner in which it is diffused. The color may also depend upon the chemical condition in which the iron exists in the clay, combined with the manner of burning. It may also be governed partly by the other constituents. Thus lime may neutralize in part the color of the iron as in the Milwaukee brick.

Range in Chemical Composition of brick clays.

Constituents.	Average per cent.	Minimum per cent.	Maximun per cent.
Silica, combined,	15.0	12.0	30.0
Silica (sand),	55.0	20.0	60.0
Alumina,	14.0	11.0	25.0
Water, combined,	4.0	3.0	9.0
Water, moisture,	2.0	0.0	6.0
Iron sesquioxide,	4.0	2.5	8.0
Lime,	1.5	0.5	7.0
Magnesia,	1.0	0.3	8.0
Alkalies,	3.5	2.0	7.0

2. Physical properties.—The plasticity of clay is determined largely by the amount of amorphous clay base or kaolin present. If this is in excess the clay may become "fat" and the shrinkage in the drying and burning become so great as to crack or craze to the injury of the brick. If the clay base is too low the clays will crack or rag in the molding and form brick of low tensile strength. The total shrinkage in the drying of the brick may vary from 4 to 20 per cent., in the burning from 2 to 8. The total average shrinkage is about 10 per cent.

As the proportion of fluxing impurities is high, generally 8 to 10 per cent., the bricks fuse easily compared with fire bricks, but they are rarely burnt at a temperature high enough to fuse them, hence a high percentage of fluxes may not be really injurious so far as the fusing is concerned, but some of the fluxes may be injurious in other ways. A high percentage of lime or even a low percentage if in lumps will weaken the brick, as in the burning it will be changed to quicklime which will slake and crumble to powder in the brick. The lime and magnesia will sometimes react on the iron greatly marring or destroying the color.

The red color of the common brick is due to iron. In the yellow clays the iron exists mostly as hydrous oxide or limonite, in the blue clays it may occur as the carbonate or sulphide or silicate or all of these. In the burning the water is driven off in part and the lower or ferrous oxide changed to the higher red ferric oxide. The color depends upon (1) the amount of iron present, (2) the manner in which it is diffused, (3) the temperature at which the bricks are burned, (4) the character of the fire whether reducing or oxidizing and (5) the relative percentage and diffusion of lime and magnesia.

Varieties of brick clays.—All the brick clays might be classified geologically on a basis of origin and mode of occurrence into (1) Residual clays, (2) Alluvial clays or stream deposits, including terrace clays, (3) glacial clays, (4) Loess clays, (5) beds interstratified with other rocks and (6) shales. Of these classes the fourth is not known to occur in Pennsylvania, but is of great value at many places in the Mississippi valley. The third does not occur in the area under discussion in western Pennsylvania, if we except the river terrace deposits, but they are quite important in many localities in northwestern and northeastern Pennsylvania, and all over northern United States. The first two classes are most widely distributed and furnish the bulk of the material for common red brick.

The residual clays are the surface clays found as soil coatings of varying depths in almost every locality and covering nearly all classes of rocks. There are few soils except the very sandy ones that do not have sufficient clay to make bricks. Nearly all the surface clays away from the immediate vicinity of the streams in central, southern and western Pennsylvania belong to this class.

The alluvial clays are deposits found along all large streams and many small stream courses, forming the river and creek bottoms and terraces. In some places this material is too sandy to make good brick, but in many places the sand and clay are in the right proportion for brick, and as the material needs no preliminary grinding, but may be thrown at once into the pug mill, it furnishes a cheap and abundant brick material.

The terraces bordering all the rivers of western Pennsylvania and their tributaries furnish large quantities of excellent brick clay, some of which is even utilized for pottery ware. A river terrace is a comparatively level platform or bench generally covered with a variable thickness of sediment deposited when the water stood at or near the height of the terrace. Some of these deposits are more than 200 feet above the present river level, and in some localities no less than four of these terraces can be clearly located. Like the river deposits now being formed, they are made up of sand, clay and boulders in varying proportions and in many places the material is of excellent quality for making red brick. In chapter VIII may be noticed the large number of brick yards in Pittsburgh and vicinity that use these terrace clays.

Beds of clay occur interstratified with the other rocks similar to the fire-clays, and if they happen to be blue or gray in color, are called fire-clay. Some of them furnish excellent material for red brick.

Shales differ from common clay in being laminated or fissile, and indurated or hardened, and generally contain more sand and foreign material. They cannot, like alluvial or terrace clay, be tempered and molded without previous grinding. They should be thoroughly ground either in rolls or pans and even then are not as plastic as many clays. Shales were and still are used extensively for making vitrified paving brick. Their excellence in making paving brick together with the improvements in machinery for grinding and handling the material probably led to the more extended usage of shales in making building brick.

Classification of building brick.—Bricks are variously classified on different bases. The common red brick are divided into common or backing brick and stock or face brick; these may be further subdivided into several grades, based on hardness or color. *Soft or salmon brick*, embracing those not hard enough for outside walls, includes such commercial varieties as soft, salmon, backing-up, pale, light, chimney, filling-in, inside-wall and foundry brick. *Stock brick*, embracing all hard enough for outside walls, may be divided into hard, common building, paving, hard building, outside, hard red, strictly hard, select hard, rough hard, hard washed, kiln-run hard, and common hard brick. The stock brick may be made from the same clay and burned in the same kiln as the common brick, but are made, handled and sorted with greater care and hence command a better price. The size of a common brick is about 8½ by 4¼ by 2¼ inches, but it may vary a quarter inch or more in length, depending on how hard it is burnt. The standard size brick adopted by the National Brick Makers' Association of Builders and the American Institute of Architects is 2¼ by 4⅛ by 8¼ inches, and the standard size press brick one-eighth of an inch thicker but the same size otherwise. This has not been universally adopted; in many localities there is a variation of one-eighth to one-half inch from these dimensions. It would certainly be desirable from many standpoints to have a standard size for the United States, but it seems difficult to get every one to agree to it.

In fancy or ornamental brick other sizes are now used in large quantities, the most common of which is the Roman or Pompeian brick, about 12 by 4 by 1½ inches, the size used in Pompeii and in many of the old Roman buildings. This size is now quite common in costly buildings, especially in buff colors and makes an attractive front where properly used. They are laid on the flat side and backed up

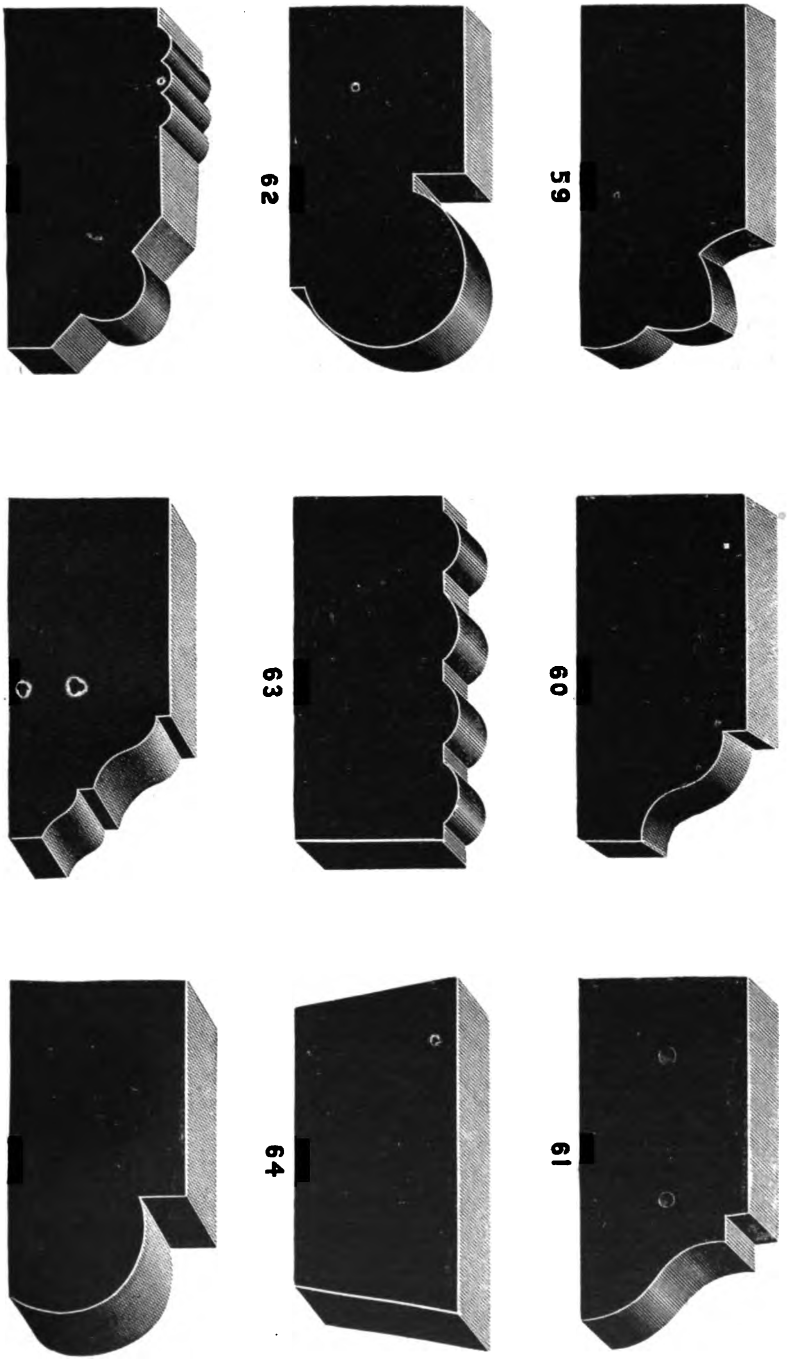

Fig. 25. Showing some of the common shapes of ornamental bricks.

with common brick. The Norman is another size not quite so common as the Roman.

Ornamental bricks for cornices, trimmings, etc., are made of a great many shapes, sizes and colors. The accompanying illustration, fig. 25, shows some of the many forms used. There is practically no limit to the number of designs and shapes and the architect is given a wide range in this line. The ornamental bricks are either dry-pressed or re-pressed. As a rule they are not made by the small operators, because it requires costly machinery, good clay, and considerable skill often gained by rather expensive experiments to make ornamental brick successfully. The ornamental red brick made in Western Pennsylvania are inconsiderable in number. The following companies make ornamental, buff and variegated brick: The Kittanning Brick and Fire Clay Co.; The Kittanning Clay Manufacturing Co.; The Fallston Fire Clay Co.; Welch, Gloninger & Co.; The Layton Fire Clay Co.; The Dunbar Fire Brick Co., and Hiram Swank's Sons. Reese, Hammond & Co. expect to be manufacturing all grades of building brick before this is published.

Enameled brick, while not manufactured in commercial quantities in western Pennsylvania at present, have been made in small quantities and much costly experimenting has been done in that line without decided success. It requires a high degree of technical skill to make enameled brick successfully. They are made in eastern Pennsylvania and elsewhere in the United States, and it is only a question of time until they will be made in quantity in western Pennsylvania.

Buff brick—Buff colored brick have been known in the market for many years but it has only been a few years since their architectural beauty and possibilities have been fully recognized and as a result their manufacture and use have increased at a remarkable rate within quite recent years, and they are now being used in large quantities, especially in our eastern cities. So far as known to the writer the first buff bricks made in the United States were made in Milwaukee and for many years Milwaukee brick and buff or light-colored brick were synonymous terms, but it is now no longer the case.

A large part of the buff brick manufactured in western Pennsylvania is shipped east. This is partly due possibly to the fact that buff brick are manufactured in greater quantities in the Mississippi valley than in the eastern states and partly due to the fact that architecture is further advanced in the eastern states than in the western states and there is a greater demand for attractive, even though more costly material. The light-colored bricks are replacing stone to some extent in the finer grade buildings.

When we consider the various shades, forms and styles of bricks we can readily see how well they are adapted to the wants of the architect, and we can hope for architectural improvements in their more extended usage.

Manganese or spotted brick.—It is sometimes desirable for architectural reasons to break a light or uniform color by other than the common red brick and one way in which it is done is by using the oxide of manganese, which is black, but sprinkled through a buff brick it may produce gray of various shades, depending on the amount used. If the manganese is used in grains or particles of considerable size, it will form dark spots in the light brick and may even give a granular appearance not unlike some granitic rocks. The variety obtainable in grain and shading, not only in the buff but in the red brick as well, by the use of manganese is very great and the brick makers are using larger quantities of it each year. Different shades of brown may be produced by mixing manganese with the red clay.* It is also used as a coloring matter for brown mortar in laying the brick.

Waterproof or vitrified brick.—Many of the buff bricks are now burnt much harder than the common building brick, not entirely to the vitrifying or glassy stage, as the name would signify, but rather an incipient vitrification more like stone than glass and which might be called lithification. These are in no way different from the vitrified paving brick, except that generally a little more care is taken in the manufacture to secure smooth surface, sharp corners and uniformity of size and color.

They have their origin in the vitrified paving brick, which no doubt suggested to builders the advantages of a vitrified brick for buildings. The advantages claimed for them are that they do not absorb water, hence form a dry wall and do not permit the vegetable growth that often disfigures and disintegrates brick walls; for the same reason dirt and dust do not collect on their surfaces so readily, hence they are much cleaner than porous bricks. The white efflorescence commonly known as saltpeter or whitewash, if it can be prevented in the drying and burning is almost if not entirely prohibited, as there is no opportunity for a solution to work through the brick, hence no chance for the efflorescence to form on the surface by weathering. They are stronger than common brick. All these qualities combine to give them an architectural value.

Rain brick.—A unique form of brick which has had a limited use in some of the western states is the rough face or rain brick. When the bricks were dried in the sun on the open drying floor, it somtimes happened that a sudden shower of rain would fall on the green bricks before they could be covered, thus producing a roughened or rain print surface. These were burnt and sold at a lower price until some enterprising architect found that they added to the beauty of a building when judiciously mingled with the smooth-faced bricks. Rain bricks were then in demand and the price advanced beyond that of the smooth brick. When it did not rain often enough to supply the demand artificial rain was produced with a hose. The writer has not observed that these ever became popular in Pennsylvania.

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*Manganese is produced in Virginia, Georgia and Arkansas and small quantities in other states. Much of it is used in making steel. Its use in brick manufacture is comparatively new but rapidly increasing in use. Much of that used in Pennsylvania comes from Virginia, and is prepared for this purpose by a company in Washington, D. C., who make a specialty of manganese for brick and mortars.

Hollow brick.—Hollow brick are generally much larger than common brick, and as the name indicates, they are hollow. Sometimes they have a simple rectangular cross section, sometimes there are one or two partitions making two or four rectangular divisions in cross sections. The advantages claimed are that the bricks can be made much larger without undue weight; an economy both of material and weight without sacrificing strength. They are now made with great variety of surface ornamentation and coloring, and may be made to give the effect of stone work where the face is roughened (which is now done in the molds) and properly colored. The cheaper, plainer forms are used in some localities for foundations, for retaining walls, for stables and even houses and store buildings. They have an extensive use in many of the Mississippi valley states, but are not manufactured or used to any noticeable extent in western Pennsylvania.

Terra cotta lumber and fire-proofing resemble in some respects the hollow brick, but they differ in that they are made porous and open in texture in order to give them light weight for use in floors and partitions in large buildings. They are hollow and can be bound by rods or bands of steel, or may furnish openings for the passage of gas pipes, electric wires, etc. The porosity is obtained by mixing sawdust in the clay, which is burnt out in burning the brick, thus leaving cavities in place of the sawdust grains. The use of this material is increasing as a substitute for wood in floors and partitions in fireproof buildings. The only factory of this material known to the writer in western Pennsylvania is the Pittsburgh Terra Cotta Lumber Co., in Pittsburgh, which is described in chapter VIII.

MACHINERY AND METHODS OF WORKING CLAY AND MANUFACTURING BRICK.

It has not been many years since all the common red brick were made from surface clay, tempered in the common upright pug-mill operated by horse power, molded by hand, dried in the sun, and burnt in the rectangular up-draft kilns with three stationary walls, and one temporary one, that is removed after the burning. A very small percentage of the brick are so made in eastern United States to-day. The upright, wooden, horse-power pug-mill and the open drying floor that could be used only two or three months in the year are now almost as much of a curiosity as the once common spinning wheel.

Methods of mining and handling the clay.—The several methods of mining are:

1. Digging by hand entirely from the base of the bank and transporting by wheelbarrow or cart.
2. To loosen the clay by plows and bring it on a road scraper.
3. Working in benches, where the clay is 30 feet or more in thickness. It is often desirable to work it on three or more benches.
4. Steam shovels are sometimes used (see Booth and Flinn, chap. VIII).
5. Undermining by wedging.
6. Blasting is often needed in shales and the harder clays.
7. It is sometimes mined in pits.
8. Where the clay has a heavy covering, as have many of the fireclays, galleries and drifts are run in as in the coal mines.
9. A belt is sometimes used as a conveyor either to move the clay from the mine or from the storage clay. Tram cars of different types are in common usage. The old method was to dig by hand and transport to the pug mill by wheelbarrow. In some of the small yards this plan is still followed; in some the horse and cart have replaced the wheelbarrow, but in most of the larger plants the clay is loaded on tram cars which are run into the works by horsepower, or by a locomotive or stationary engine. In one of the largest brickworks in western Pennsylvania (Booth and Flinn's) the clay is loaded on the tram cars with a steam shovel. The same company also uses a train of self-dumping cars, which combined with the steam shovel enables them to handle clay very rapidly. See fig. 43. Sometimes the clay is carried to the mill on a traveling belt. See fig. 29. In the works of the Cambria Iron Co., at Johnstown, the clay is carried from the storage shed to the machine by a belt.

Grinding and tempering.—Different methods are employed for grinding and tempering the clay. One of the most primitive methods is to tramp it with cattle or horses, a process it is hardly necessary to state that is not in vogue in this State. The most primitive method in use in Pennsylvania is the upright wooden pug mill, run by one horse. Another allied method is that in which a large wheel is put on a long shaft, one end of which is held by a vertical pin in the centre of the clay to be mixed; to the other end is attached a horse which travels in a circle about the clay dragging the wheel through it. This process proves to be a very effective, but very slow, one with certain grades of clay.

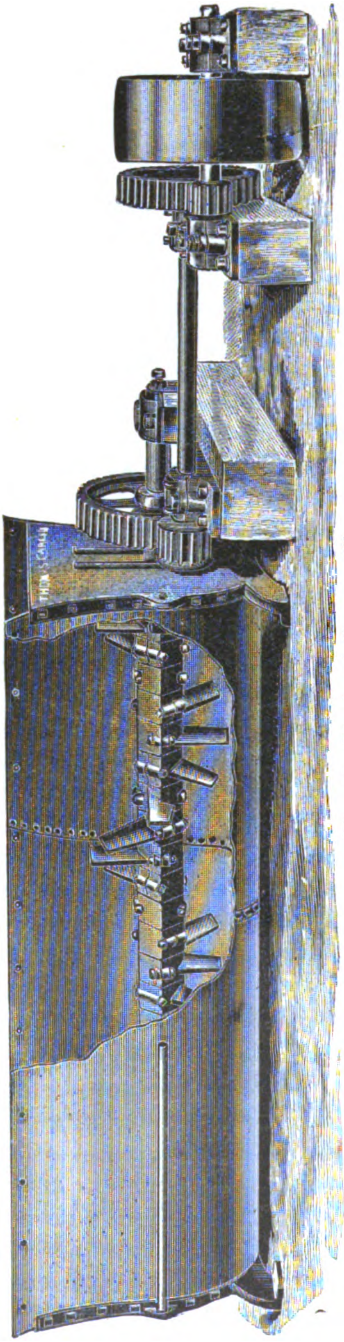

Fig. 28. Horizontal pug mill.

Where the clay is of such a character that it can be mixed without previous grinding, the horizontal steam power pug mill is most commonly used. These are of numerous sizes and varieties but all work on the same principle. Fig. 26 shows a typical form of the horizontal pug mill.

Much of the clay and all of the shale used in brick-making is first ground before tempering, which may be done in a wet pan (see fig. 19, but may be done in a dry pan (see fig. 20), or by a roller or crushing machine, of which there are numerous types. The very hard material is sometimes first put through a common rock crusher before it is put into the dry pan or disintegrator. After grinding, the clay is elevated and screened as with the fire-clay and is then tempered in the pug mill which may form part of the molding machine or may be separate.

Molding the bricks.—The old method, which is still in use for making fire brick, but is now abandoned for making building brick, except in the small or temporary yards or for intricate shapes, was to mold by hand. The machines are rapidly displacing all the handworkers because of the greater cheapness with which brick can be produced, and the improved quality of the brick at least for certain purposes. The average days's work for a molder and two off-bearers is 4,000 bricks (in some places 3,000)* while a brick machine will turn out 15,000 to 100,000 or more, depending upon the size and make of the machine.

One of the first brick machines of which I find any account in this country was made in Philadelphia in 1840. It was a soft clay machine operated by horse power, and was destroyed in a riot by brickmakers seven years later, on the plea that it would take bread from the mouths of the workmen. In the same year (1847) a dry clay machine was made in Philadelphia.†

Nathaniel Adams, of Cornwall, N. Y., is said‡ to have taken out a patent for a brick machine between the years 1830 and 1840, one type of which is said to be still in use.

It has been within comparatively recent times, in fact within the last 20 years, that most of the brick of this country have been molded by machinery.

The many different kinds of brick-molding machines are divided into two classes; the soft-mud and the stiff-mud machines. The soft-mud machine more nearly resembles hand-molding than the stiff-mud. The clay is forced into molds similar to the hand molds and the top surface scraped by the machine, thus making a brick with one rough face. The number of bricks molded at a time varies with the size of the machine. One molding six at a time is quite common. The molds are removed and empty ones put in by the off-bearers. Fig. 27 shows one type of soft-mud machine used quite extensively in western Pennsylvania. It is manufactured at Lancaster in this State, and has been in use since 1858, but there have been several improvements since it was first put on the market.

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*In 1832, in Cincinnati, the molding of 9,000 bricks was a regular day's work. In a contest between two expert molders, working from sunrise to sunset, one made 24,700, the other 25,470. The results were about the same at a similar contest in Philadelphia at a later date.—Trans. Civ. Eng., Vol. 25, p. 362.

†Trans. Civ. Eng., Vol. 25, page 362.

‡Brick, Chicago, Dec., 1897, Vol. VII, No. 6, p. 225.

The stiff-mud auger machines are of many sizes and styles. The main feature of all is that the clay is forced out through a die in a continuous bar which is cut by wires into the sizes desired. The bar of clay may be of any size desired and the cutting may be done in different ways. It is generally done by wires, and may be either by hand or automatic. The hand-cutting machines (fig. 28) may cut any number of bricks at a time, depending upon the size of the table and the number of wires. Twelve is a common number, but sometimes as many as 18 are cut at once. The bricks are delivered on a board which is removed by the workman and another put in its place. The bricks may be side cut, end cut, or edge cut, the first being the most common with hand-cutting machines, the second the most common with the automatic.

The same machine may be changed from a side-cutting to an end-cutting by changing the size of the bar of clay which is done by changing the die on the end of the machine. Sometimes two or more bars of clay may be delivered at once and the capacity of such a machine is only limited by the amount of clay that can be fed into it. Figure 29 shows the action of an automatic end-cutting brick machine. In most of the more modern plants the bricks instead of being loaded on a wheelbarrow, as shown in the illustration, are loaded on an iron car, which is then run into the drying tunnels. Not only the common-sized brick, but those of any desired size, even hollow brick and tiling may be made on a machine of this kind by simply changing the die through which the clay is forced. There is scarcely any limit to the variety of products that may be made on a machine of this kind. The molding machine and pug mill may be combined in one or may be separate. While a great many different machines are used in western Pennsylvania, the most common soft-mud machine is the Henry Martin machine, made in Lancaster, Pa., and the most common side-cut, stiff-mud machine is the Freese, made in Gallion, Ohio.

There is another type of stiff-mud machine that differs from the auger machine in forcing the clay through the die by a stroke of the piston and consequently the flow of the bar of clay is intermittent instead of a continuous stream as in the auger machine. No ma-

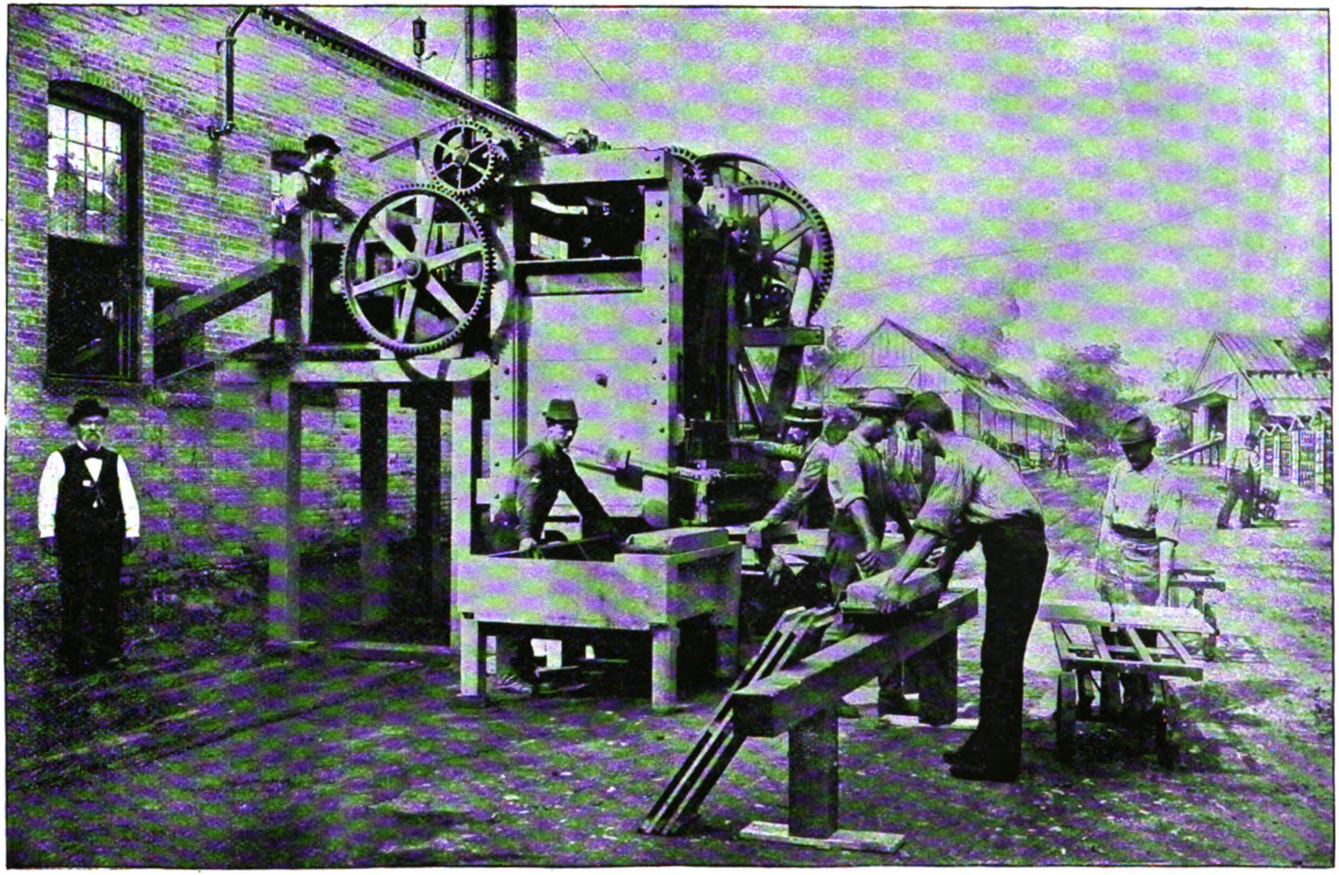

Fig. 27. View of soft-mud brick molding machine, clay elevator and pug mill at work.

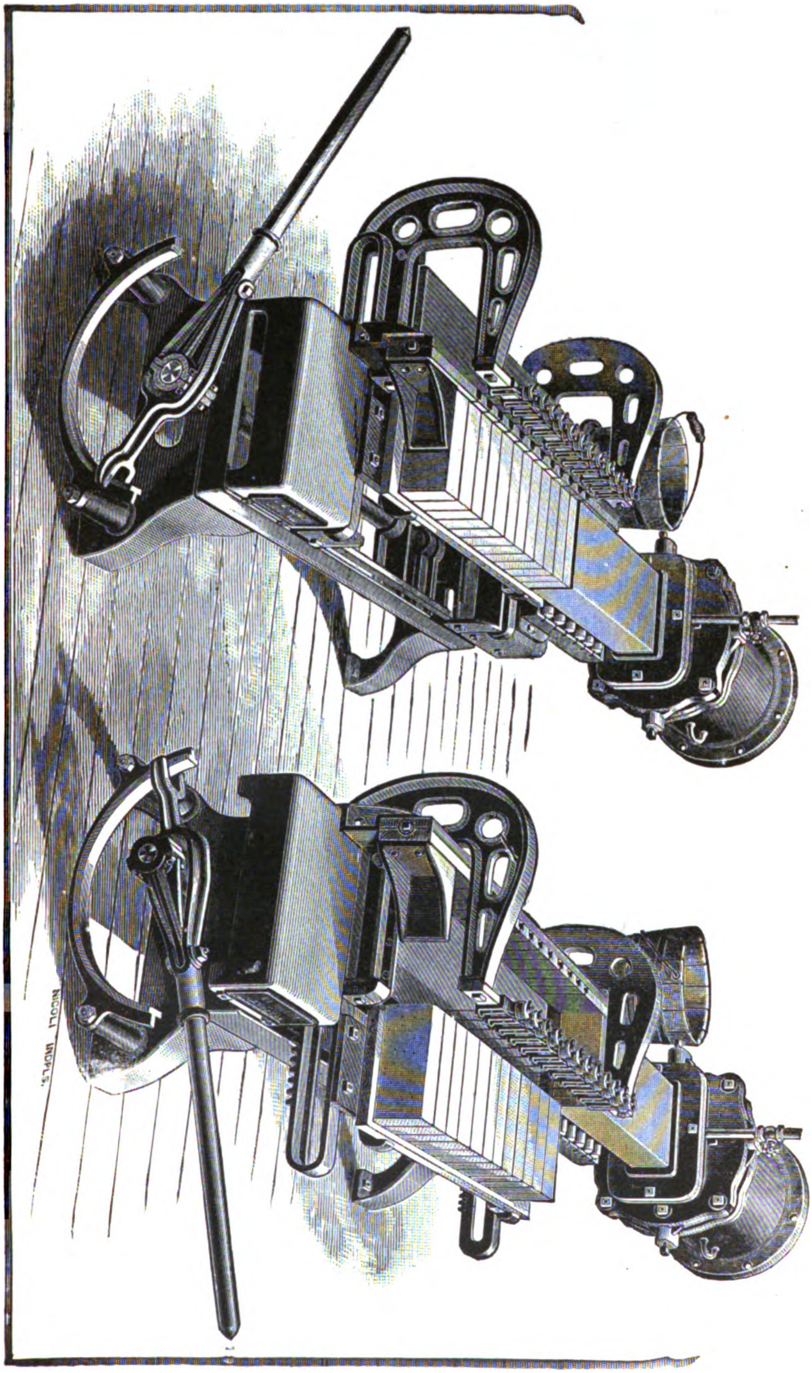
NICOLI INDPLS.

Fig. 28. Two views, hand-cutting, stiff-mud, improved pattern, board delivery brick molding machine.

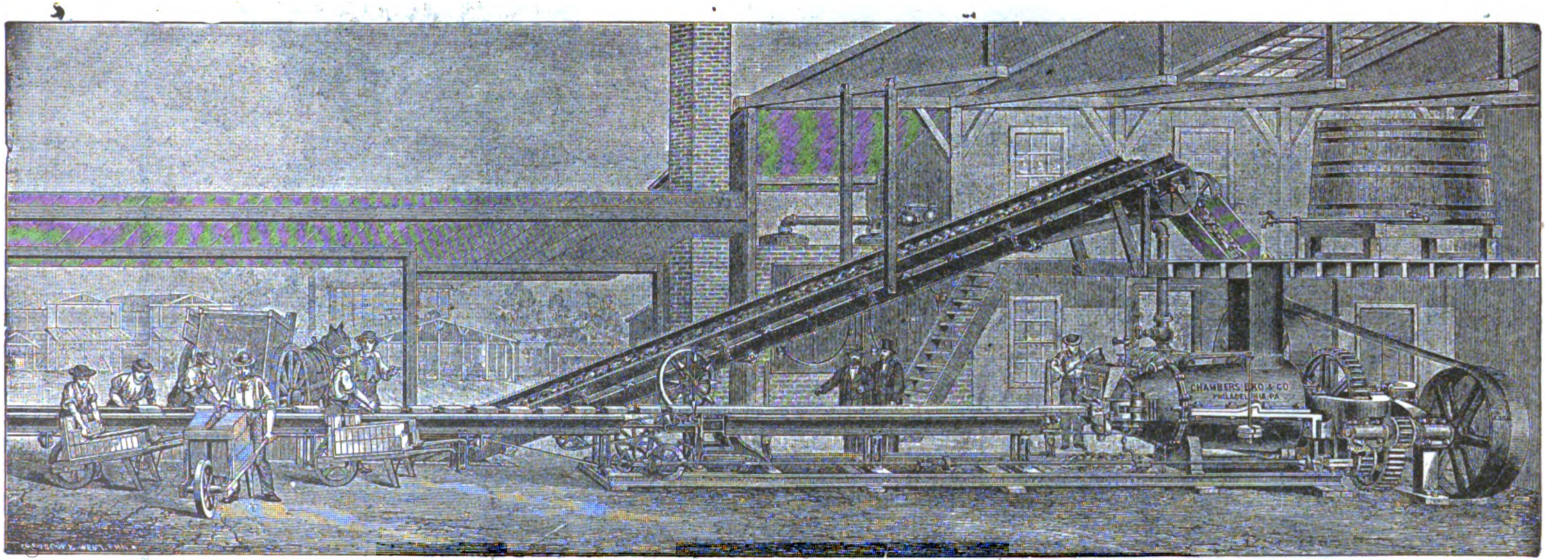

Fig. 29. An automatic, stiff-mud, wire-cut, brick molding machine at work.

chines of this type were observed in the factories in western Pennsylvania, although they are said to be quite common in Ohio.

An attempt at a combination of these two types has been tried in at least two different machines described by Prof. Orton in his report on the clay industries of Ohio.* None of these were observed in western Pennsylvania.

Repressing.—Whether molded by hand or machine the clay that is plastic enough to mold easily is subject to mishaps, as in handling the corners and edges will be crumbled. If not always kept on a level surface it will warp or bend in the drying and all machine-made bricks will have at least one if not two rough surfaces. To remedy these defects and produce a more regular smooth and shapely brick, they are re-pressed either by hand or steam power. This extra handling of the brick is expensive and of course increases the price of the brick, as it increases the quality. The process is not essentially different from that in the fire-brick works (see fig 22). The re-pressed bricks are denser and supposed to be stronger than those not repressed.

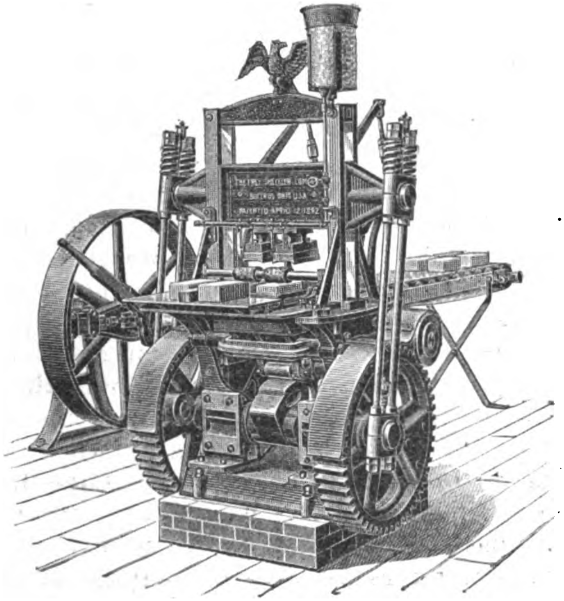

Fig. 30. Steam-power, brick, repressing machine.

Dry press.—Some bricks are made in manner similar to that used in making tile, in which the clay instead of being mixed into a plastic mass with water is molded dry or with only sufficient moisture to cause the dust to cohere when pressed in the mold. This process makes a very dense brick with smooth even surfaces, very desirable for many architectural purposes. They can be taken directly to the burning kiln from the machine without the intermediate drying. In spite of this, however, the process is more expensive.

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*Geol. Surv. of Ohio, Vol. VII, p. 161.

Drying.—The old method of drying was to spread the bricks out in the sun on a level area. This process has now been abandoned by all but a few small yards which operate only at rare intervals. The next stage was to put a covering over the drying floor to protect the bricks from the rainfall and then heat the floor artificially. This is in use yet in many places. Another advance following the use of the improved machinery is the tunnel dryer. These are of different types; in some the tunnels are heated by fires built underneath the track, as at the yard of the Cambria Iron Co. Sometimes the tunnel is heated by steam pipes, sometimes by hot air. In the progressive tunnels, the cars are run in at one end and when the next car is put in it is pushed forward a car length and is thus moved slowly to the other end of the tunnel, the rate being so regulated that the bricks are dry enough to stack in the burning kiln when they reach the far end of the drying tunnel. Figure 31 shows such a tunnel. At the extreme right a car loaded with green brick may be seen entering the tunnel; at the left a car of dried brick has just emerged on its way to the kilns.

Burning.—After the bricks are dried they are stacked in the kilns and burnt, which is the final stage of manufacture. The different fuels used are wood, coal, natural gas and petroleum. There are now many different types of kilns in use. A few years ago all the red brick were burned in the common, rectangular up-draft kiln which had three permanent walls, the third being removable, the heat coming from fires built at the bottom and winding its way up through the bricks, escaping at the top. In the down-draft kilns the gases are drawn off at the bottom of the kiln and find their way to an outside chimney. Sometimes one stack will serve for four or more kilns. Many of the down-draft kilns are circular in outline, but some are rectangular. There are many patent kilns in this class all claiming some special improvements. The continuous kiln is used in a few places and will no doubt be used more extensively in the future when its merits are fully known and appreciated, and its manipulation is better understood.

Booth and Flinn, and Harbison and Walker, at Pittsburgh, and Welch, Gloninger & Co., at Monaca, each use the continuous kiln. The Westmoreland Fire Brick Co., at Hunker's Station, have one in their works, but it has not been used for several years.

The accompanying illustration (Fig. 32) shows the plan of a modern brick plant, giving the relative position of the machinery, kilns, dryer, etc.

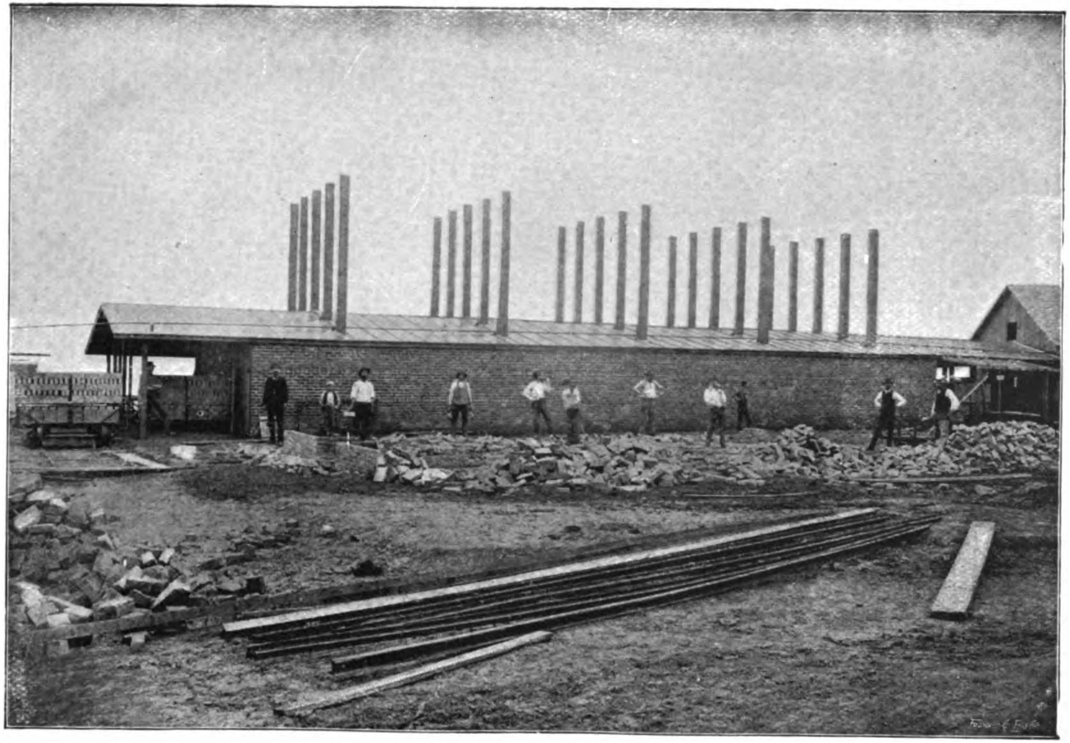

Fig. 31. The progressive Bucyrus drying turnel.

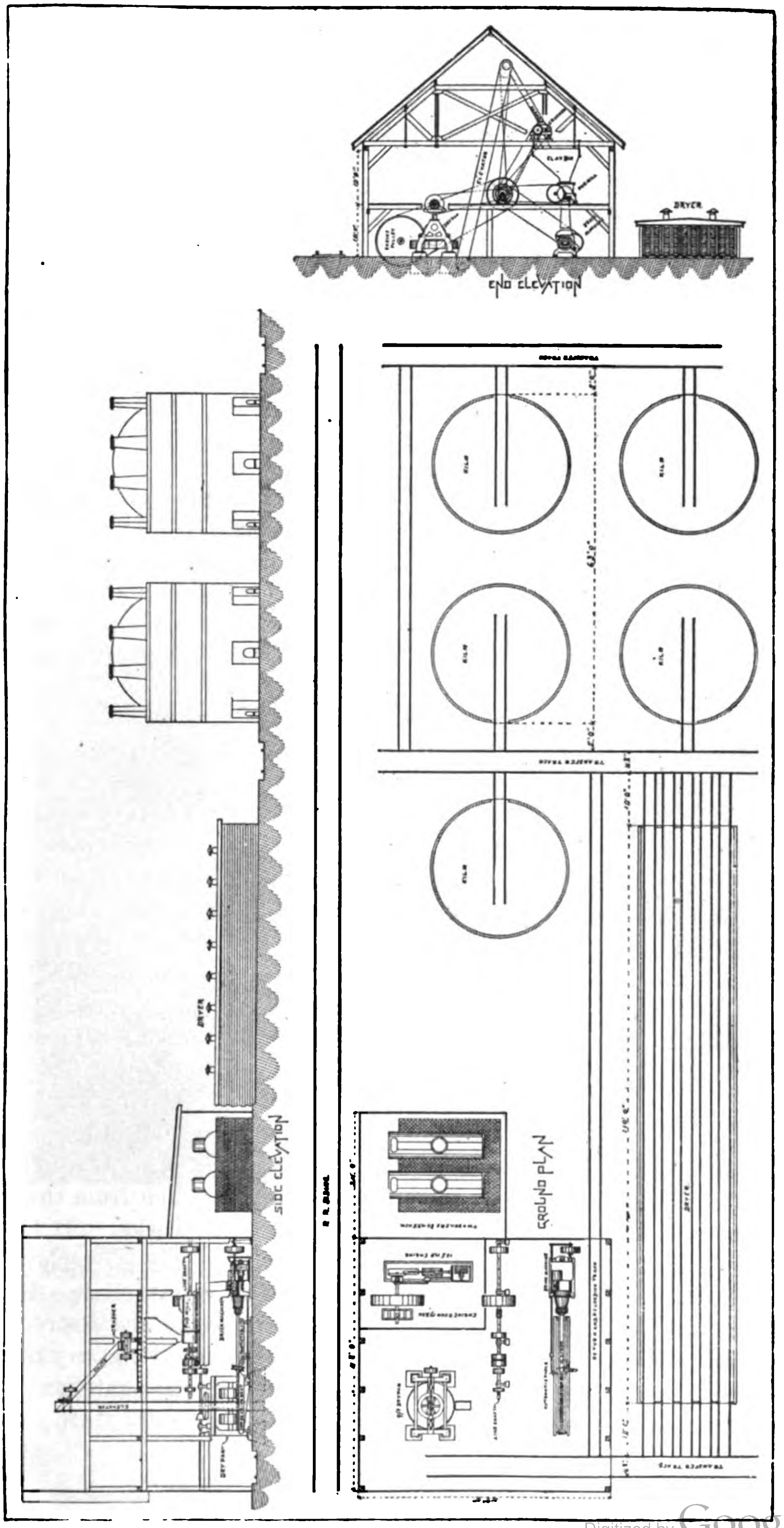

Fig. 32. Plan and elevation of a modern brick-making plant.

CHAPTER VII.

RED AND BUFF BUILDING BRICK INDUSTRY IN WESTERN PENNSYLVANIA.

A considerable number of the brick companies mentioned on the accompanying table are small and do a strictly local business, sometimes supplying the home market entirely, sometimes only in part. A number of them ship brick to neighboring towns and several who make the finer grade bricks ship to other states. The manufacture of common red building brick reaches its maximum importance in Allegheny county, as shown in the following chapter. High grade building brick are made at Kittanning, Fallston, Vanport, Layton and Bolivar.

Ohio and Beaver Valley brick works.—The Ohio valley works in Allegheny county are described in Chapter VIII.

There is a small brick yard on the river bank at the upper end of Rochester, where common red building brick are manufactured to partially supply the local demand. The bricks are made from the alluvium of the river bank and burnt in the common, open-topped, up-draft kilns.

The two large brick works at Monaca across the river from Rochester, manufacture some building brick, but only as side issues (see fire brick and paving brick).

The Vanport Brick Co., at Vanport, Pa., have manufactured large quantities of building brick. At the time of my visit, September, 1897, the works were idle, owing to some financial troubles in the company. The works have been in operation for about 30 years. They were first operated by Mr. S. R. Mitchell, who was followed by Mr. John Russell. The Vanport Fire Clay Co. was in possession from 1881 to 1897. The works are now, 1898, operated by the Vanport Brick Co., who make a nice grade of building brick and have a capacity of about 20,000 per day. The bricks are machine made in a stiff-mud wire-cut machine, using both hand and steam re-press machines. The bricks are dried on the car in a hot-air drying room and burnt in five round down-draft kilns. Pittsburgh and the neighboring towns form the chief market. The bulk of the clay used was taken from the bed of Lower Kittanning fire-clay on the bluff at the works. It has a workable thickness of from 10 to 12 feet. The fire-clay is overlain by about 20 inches of coal and 15 feet or more of soft yellow shale. Some of the shale is mixed with the clay when red bricks are desired, as the clay alone burns a light color. The terrace clay at the works has been used to some extent for the same purpose as the shale, namely, to color the brick.

Welch, Gloninger and Co's works, immediately adjoining those of the Vanport Brick Co., manufactures some building brick from the same kind of materials, but their chief trade is in fire brick, the building brick being a side issue. (See p. 68.)

The Fallston Fire Clay Co., near Fallston, in the Beaver valley, is one of the prosperous manufacturers of high grade building brick. They make some fire brick and paving brick, but their chief business is high class buff building brick of different shades and forms. They manufacture all the standard sizes, such as Pompeian, Norman, and common and ornamental brick of different patterns. Their largest market is in the eastern states, and while they ship some to Pittsburgh and neighboring towns the bulk of their trade is in the more eastern cities. They have been in operation for six years (since 1891) and

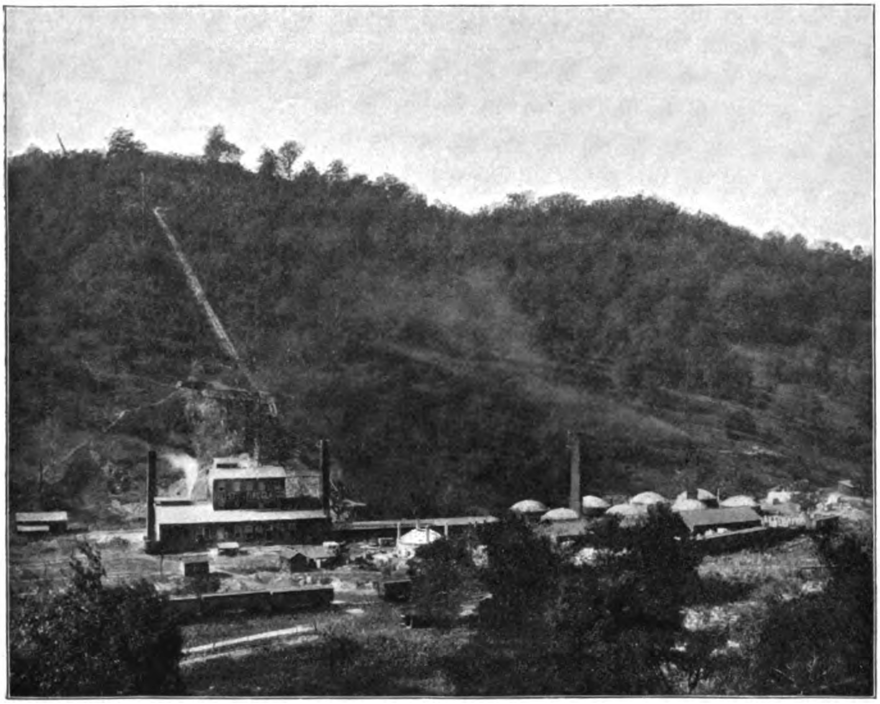

Fig. 33. Showing the works and mines of a Clay Co., in Beaver Co. The first mine above the main building is in the Lower Kittanning clay, and the upper one at the top of the long incline is in the Freeport clay.

have a capacity of 18,000 to 20,000 bricks per day. Nearly all their brick are re-pressed, dried in a steam drying tunnel and burnt in down-draft kilns.

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Most of their clay is obtained from the bed of Lower Kittanning clay that is used so extensively in the potteries and brick works in this vicinity and which outcrops in the bluff at the works. They use some clay from the Freeport bed, higher on the hill, 170 feet above the Kittanning clay. Small quantities of shale from the bluff at the works are used for coloring material when different shades are desired. It is the aim of the progressive and enterprising manager to keep the works up to date both in the grade and in the colors of the bricks manufactured. The accompanying illustration, fig. 33, shows the works of the Fallston Fire Clay Co. and the relative positions of the clay mines and the facilities for delivering the clay to the works by the incline track and dump.

The Brady's Run Fire Clay Co, whose works adjoin those of the Fallston Co., manufacture some building brick but their chief trade is in paving brick. The property is now controlled by the Park Fire Clay Co., but still retains the name of the former company.

A. Dewhirst & Bro., New Brighton, Pennsylvania, operate a brick yard for the manufacture of common red brick on Marion Hill, about a mile southeast of New Brighton. The terrace clay is used, a thickness of four or five feet being worked from the surface. They have worked over an area of several acres, as the company has been operating for 23 years. They claim to have furnished much of the red brick that has been used for building in New Brighton and Beaver Falls, where all their product has been used. The clay is ground in an old style pug mill and the bricks molded by hand and burnt in the common open-top, up-draft kiln. There are two kilns with a capacity of 200,000 each.

A red brick works somewhat similar to the above, said to be owned by T. Dewhirst, is located on another part of Marion Hill, but is not in operation at present.

Mr. A. F. Smith & Son, who own the two fire-brick works at New Brighton, make some building brick along with the fire brick. They operated a red brick works on the hill above the present brick yard from 1852 until five or six years ago. The bricks were made from the yellow clay of the same terrace deposit as that used at the Dewhirst yard above. The flower pot industry of New Brighton is said to have started at this yard.

Levi Fish & Sons are said to have operated a red brick yard for many years on the hill near the Oak Hill pottery, and about a quarter of a mile east of the pottery. It is on the same terrace as the Smith and Dewhirst yards. It has been idle for many years and no particulars can be given.

BUILDING BRICK IN THE ALLEGHENY VALLEY. *

Freeport.—There is an abandoned brick yard about half a mile north of Freeport, on the west bank of Buffalo creek. The clay was obtained from the alluvial deposit on the creek bank and only common red bricks were manufactured. It is said to have been idle for three or four years and is now (August, '97) advertised for sale.

Ford City.—The Manor Brick Co. has operated a brick yard at Ford City since 1888, but the present officers of the company have had control of the works for only one year. G. B. Daugherty & Son started a yard adjoining this one at the same time, each company having a contract to furnish five million bricks for the large buildings of the Pittsburgh Plate Glass Works at Ford City. The Daugherty Company stopped when their contract was fulfilled but the other company continued filling other small orders, and a few years later had another order from the glass works for 11,000,000 bricks. They are now shipping bricks to Butler and have shipped to various points in the Allegheny valley.

They now use a wire-cut stiff-mud machine, with a capacity of 15,000 per day. They formerly used a soft-mud machine, with a normal capacity of 20,000 per day, but often run to 25,000 or 30,000 per day. They formerly used the clay from the river terrace deposit on which the town is situated, but they now use clay and shale from the river bluff back of the town, from which the clay is transported on a short tramway to the works. A section of the bluff shows the following strata:

Section of river bluff at the clay mine at Ford City.

Limestone, 8 feet.
Shale and clay, 3 feet.
Coal, 2 inches.
Fire-clay, 10 feet.
Blue-gray shale, 20 feet.
Coal, 2 feet.
Fire-clay, 8 feet.

The upper fire-clay and the shale are used for making brick. The lower fire-clay is not used. The clay and shale are ground in a dry pan, screened and mixed in a pug mill ready for use. Red building brick only are manufactured.

The Kittanning Clay Manufacturing Co. began operations in 1896, and is now fairly under way. J. H. Painter is president and Hon. G. W. McNees, secretary and general manager. The works are located in the ravine about 300 yards north of east of the A. V. R. R.

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*See the following chapter, Chapter VIII, for works along the lower Allegheny Valley in Allegheny county.

depot in Kittanning. They manufacture red and buff building brick, red paving brick, fire brick, pressed brick, Pompeian brick, drain tile and chimney tops and lime.

The varieties of brick and tile are obtained by different admixtures of shale and fire-clay from their quarry located at the works.

Section of the clay and shale bank at works of the Kittanning Clay Manufacturing Co.

1. Soft brown shale, 30 feet.
2. Coal (Kittanning), 3 feet.
3. Fire-clay, 10 to 12 feet.
4. Blue-gray shales weathering yellow-brown, 15 feet.
5. Iron ore, 1 foot.
6. Limestone, 10 feet.
7. Fissile shale, 20 feet.
8. Soft fire-clay (reported), 10 feet.

Only numbers 1, 3 and 4 in the section are used for making brick.

The coal is mined for use in the town, but it is not used at the works, as the burning is done with natural gas, which is true of all the works in this vicinity. The limestone is quarried and burnt into lime for local usage. The soft fire-clay, number 8, and the lower part of number 7 are concealed below the bottom of the valley. The thickness given is that reported from borings. The clay and shale are ground in a dry pan screened, mixed in a pug mill and molded in a wire-cut stiff-mud machine. The tile are made in a similar type machine which cuts two pieces at a time. In the tile machine the clay is forced through an annular die in a continuous clay tube, which is cut by the wires into the lengths desired just as the clay bar is cut on the brick machine. They use two rectangular up-draft kilns and four round down-draft kilns.

The accompanying view (Fig. 34) shows the favorable location of these works. The clay and shale quarry, only partly visible on the right, at an elevation slightly above the works permits the materials to be cheaply moved to the grinding pans. Gas is furnished at the works from the neighboring pipe lines. The works are but a few hundred yards from the Allegheny Valley railroad with which they are connected by a side track, and over which the products are shipped.

The work of the company this year has been largely experimental, to determine the character of the clays, and the products for which it is best adapted. The following analyses made at State College shows the chemical character of the materials used.

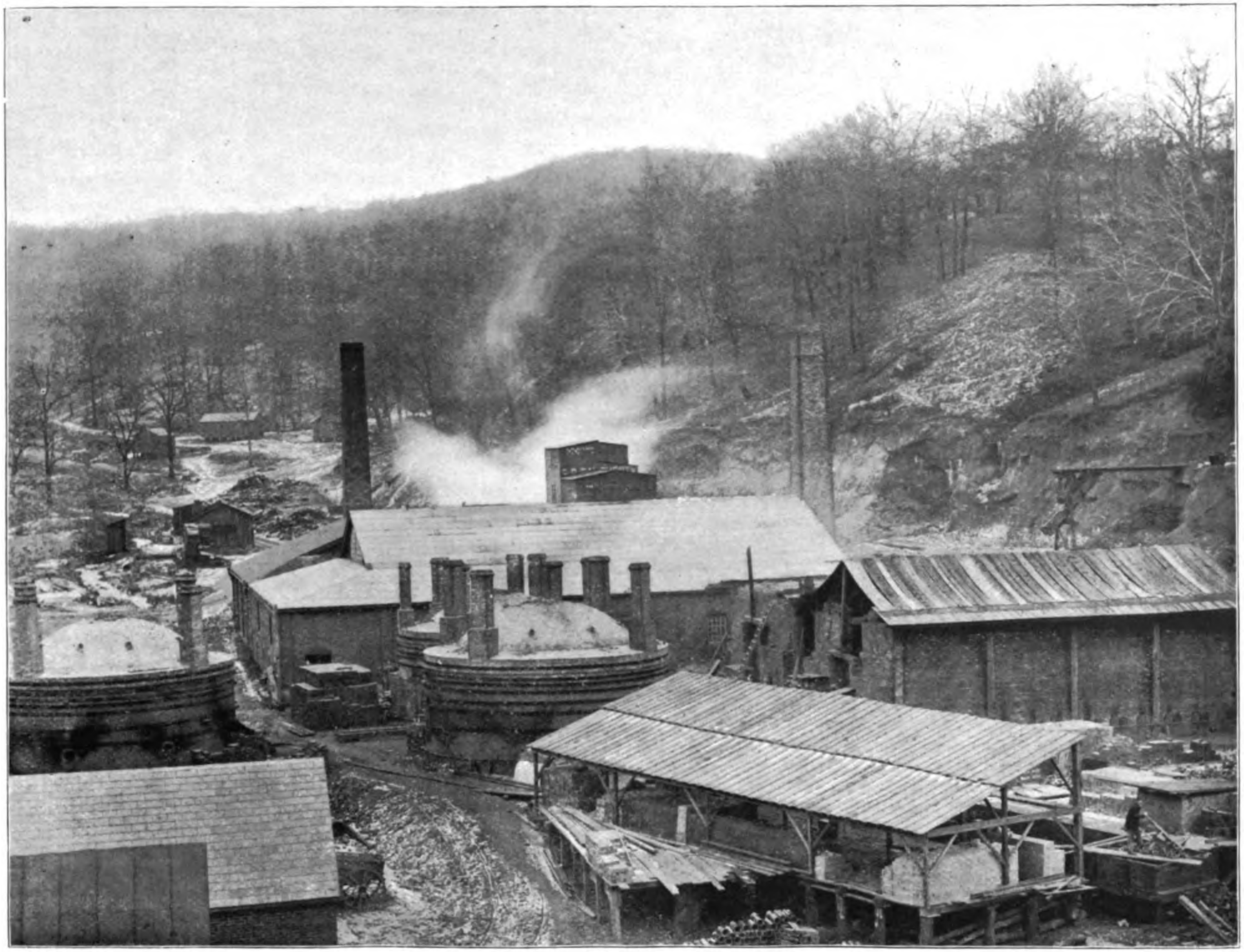

Fig 34. View of portion of the works and clay pits, Kittanning Pa. Clay pits on the right. Kittanning fire-clay and shales.

Analyses of Kittanning clay and shales.

	1	4	7
Silica (SiO^2),	53.31	55.17	59.80
Alumina (Al^2O^3),	24.54	19.92	19.72
Iron oxide, (Fe^2O^3),	8.75	12.01	5.92
Loss on ignition (H^2O etc.),	8.55	6.81	8.59
Oxide of manganese (MnO^2),	0.38	....	....
	95.53	93.91	94.03

Analysis of fire-clay No. 3.

Silica (SiO^2),	60.40
Alumina (Al^2O^3),	26.23
Ferric oxide (Fe^2O^3),	1.34
Ferrous oxide (FeO),	0.23
Lime (CaO),	.14
Magnesia (MgO),	.54
Potash (K^2O),	2.66
Soda (Na^2O),	.28
Loss on ignition (H^2O etc.),	8.71
Total,	100.53

The numbers at the head of the analyses correspond to the numbers on the foregoing section of the bluff at the clay works. No. 3 is the fire clay underneath the Kittanning (Lower Kittanning) coal and at the same geological horizon as the clay mined so extensively at New Brighton and vicinity in Beaver county. Compare the analysis with that of some of the New Brighton clays (Table XI, Chapter IX). The analysis would indicate a clay suitable for stoneware and all varieties of building and paving brick, or a fire brick of low refractory power. Where red brick or tile is required with this strong body it could be obtained by mixing the shales of analyses 1, 3 and 4. These shales could be used alone for making red brick or drain tile and the fire-clay could be used alone or with a very slight admixture of shale for making vitrified brick.

The abundance of clay and shale material associated with the coal and an abundant supply of natural gas offers favorable advantages for the manufacture of various clay products at this locality.

The Kittanning Brick and Fire Clay Co. operates a brick works on the east side of the Allegheny Valley railroad about two miles above Kittanning. They have been in operation three years, have ten kilns, and are well equipped with machinery having a normal capacity of 24,000 bricks per day, but often exceeding that amount. The chief business of the company is in making a high class buff and gray building brick. They claim to make one of the nicest building bricks on the market. They sell some paving brick and some fire brick, but these are mainly culls from the building brick, such as those lacking a uniform or a pleasing color which lowers their value for fine building brick, but are as good for paving or fire brick as those more uniform in color. As might be expected the fire brick are not highly refractory as all are partially fused (vitrified) in the burning. Besides the common sized brick they make the Pompeian, the Norman and ornamental brick of different kinds. They also make the dark brown and gray (manganese) spotted brick. The bricks are all carefully sorted as they come from the kiln to get uniformity of shade, and the odd shades laid aside for small orders or for paving brick. While they ship many bricks to Pittsburgh and vicinity, their largest markets are Boston, New York and other eastern cities. As they make only high grade brick, they command good prices, which justify shipping to more distant points than common bricks.

The bricks are made from fire-clay which is obtained from the mine on the hill above the works, and which is run by gravity down an incline railway into the works. The bed is said to be about 9 feet thick, the upper 6 feet being a light gray color and the lower 3 feet a dark color. The clay is ground in a dry pan, screened, mixed in a pug mill and run into the wire-cut machine. Some of the bricks are cut on the edge, thus giving the broad face smooth and some are re-pressed. All are burnt in the down-draft kilns with natural gas. The company is crowded with orders at present and apparently doing a prosperous business. The Pittsburgh office is at the foot of 10th street, and Mr. Sherwood C. Martin is president and manager.

BUILDING BRICK IN THE KISKIMINITAS AND CONEMAUGH VALLEYS.

The building brick industry in the Conemaugh valley is not extensive, there being only four works in operation, three idle, and one about to start.

Hyde Park.—The first brick works met in active operation in ascending the Kiskiminitas river is at the little village of Hyde Park, is operated by Kuhn and Schaeffer, and has been in operation about five years. They now have a capacity of 40,000 bricks per day, but rarely run to full capacity. They make red paving brick and building brick, which are all made on a wire-cut, stiff-mud machine, which cuts 13 bricks at a time. The material is ground in a dry pan, screened, mixed in a pug mill and fed into the brick machine.

The material used is bluish-brown shale quarried in the river bluff at the works. It contains a great many "iron balls," iron carbonate, and iron oxide, which are picked out by hand as the shale is quarried. There is a river deposit a few feet in thickness overlying the shale and consisting of sand, clay and boulders, all of which, except the boulders, are used with the shale in making brick.

The first efforts at brick making here were evidently attended with difficulty, as there are large masses of fused brick in the debris at the works caused by errors in the burning. The temperature would get too high for the quality of the clay used, and the result would be a melting and running together of the brick. Possibly not all of the iron balls were removed. They claim to have remedied this defect and are now making brick successfully under another foreman.

There is a small abandoned red-brick yard on the south side of the river at Leechburg, where red bricks were made from shale. There is a small abandoned yard on the south side of the river at Avondale station on the West Penn R. R., where the alluvium of the river valley was used. Apparently the yard has not been in operation for several years.

Blairsville.—The brick yard at Blairsville, owned by E. J. Graff, has been in operation for seven years. It has been leased and operated by the J. D. Neff Brick Co. since March, 1897. They manufacture red building brick from shale, and have made a few light colored brick, but not in commercial quantities. The capacity is given at 300,000 per year. The yard is located on the Indiana Branch Railroad, about a mile north of Blairsville. The principal markets are along the Pennnsylvania Railroad between Altoona and Greensburg.

Blairsville Intersection.—On the south side of the Pennsylvania railroad about 300 yards west of the Blairsville intersection is a brick yard owned by J. K. Stark, of Greensburg, and operated by the Branch Brick Co., with Mr. Gwinn as superintendent. They make red brick only. The material used is shale, which is ground in a dry pan and molded in a wire-cut stiff-mud machine, which cuts eleven bricks at a time and has a capacity of 20,000 per day. The markets are points along the Pennsylvania Railroad west of the Intersection. The strata dip about ten degrees to the south of west and the part used for brick shows from three to four feet of yellow, sandy clay underlain by ten feet of crumbling brown shale, underlain by a lumpy blue to yellow clay, both the shale and underclay being impregnated with iron.

Reese, Hammond & Co., at Bolivar, are now adding a building and paving brick addition to their fire brick works (see page 83).

Louis Whein, of Johnstown, is said to be the operator of a small red brick yard at Sheridan, three miles below Johnstown, on the Pennsylvania Railroad. It is in operation on a small scale at irregular intervals.

Johnstown.—The Cambria Iron Co. has operated a brick yard in Johnstown for thirteen years or more. The yard is situated between the Pennsylvania Railroad and the Conemaugh river, about a mile below the iron furnaces of the company. They make a few pressed brick but most of the output is common red brick. The capacity is 30,000 per day and most of the product is used in Johnstown.

The works are well equipped with modern machinery and appliances. The clay is obtained up the river near the coke ovens and is brought to the works on the railway. The cars are run up on an elevated trestle under a large shed and the clay unloaded in two long parallel heaps, where it is left to dry. From the drier portions of this heap clay is shovelled by workmen on a traveling belt running between the heaps, by means of which it is carried to the dry pans, where it is ground and goes through the pug mill to the brick machine, an automatic wire-cut machine, which runs the bricks out on a belt, from which they are taken and assorted, the sound ones being put on a metal car, whence they are transferred to the drying oven where they are dried over a coke fire and then transferred on the same car to the burning kiln.

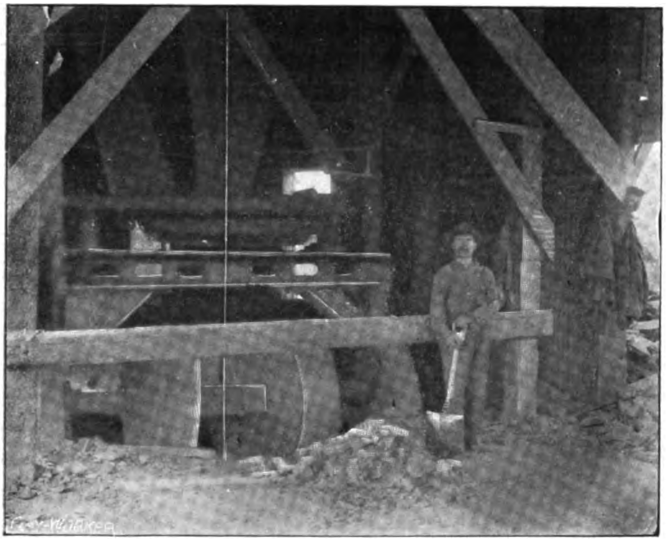

Fig. 35. Photo of a dry pan in operation.

BRICK YARDS BETWEEN THE CONEMAUGH AND THE YOUGHIOGHENY RIVERS.

The brick yards along the Pennsylvania Railroad between Wall and Pittsburgh, that is, all in Allegheny county, are described by Mr. Affelder in Chapter VIII. Between Wall and Blairsville Intersection there is a number of small brick yards but the only ones of more than local interest are those at Irwin and Rumbaugh station, both belonging to the J. M. Rumbaugh Brick Co., of Greensburg, which company does a large business, the principal market being along the Pennsylvania Railroad between Altoona, Pittsburgh and Uniontown.

The Irwin yard was operated by the Irwin Red Brick Co. for several years but has been controlled by the J. M. Rumbaugh Brick Co. since January, 1896. The daily capacity is 30,000 red bricks, all made by machinery, part on the stiff-mud wire-cut and part on the soft-mud machines. They make some re-pressed brick. The bricks are made from shale obtained from a bed forty feet or more in thickness. A bed of blue-gray sandstone runs through the shale about fifteen feet from the bottom of the opening. The shale overlying the sandstone is softer, more crumbling and yellower than that underneath.

The works at Rumbaugh station (Calumet P. O.) have a capacity of 70,000 per day and have been in operation about nine years, the first four years by Mr. Rumbaugh alone, since then by the J. M. Rumbaugh Brick Co. They make red building brick, some re-pressed and soft-mud brick and all are machine made.

The bricks are made of shale which is quarried near the works and run into the yard on a tramway. The shale is worked to a depth of fifteen to twenty-five feet, the lower part having a blue-gray color, the upper part oxidized to a yellow-brown and more crumbling than the fresh portions. It burns to a bright red.

The bricks made by this company in its three different yards include high grade, handsome red building brick and the common red building brick. The favorable location of the yards for shipping combined with the quality of bricks produced, gives them a large market along the Pennsylvania Railroad.

W. W. Parks has operated a brick yard in Greensburg for the past eight years that has a daily capacity of 7,000 bricks and produces both common and pressed brick. The material used is a mixture of shale and sandstone. The shale alone is said to burn a pale color and the sand is used to give the brick a bright color.

The Standard Brick Co., at Jeannette, has operated a brick yard at that place for the last five years. It was operated by another company three years before it came into the possession of the Standard Co. They use a Martin soft-mud machine with a nominal capacity of 15,000, but frequently reached 18,000 per day. The bricks were made from shale and the company has used all the raw material in its possession and is now (July, 1897) stopping work for lack of material. They made a few pressed brick but most of the output was common red brick. The output for 1896 was about 3,000,000 bricks.

At Latrobe there are two small brick yards that are in operation at irregular intervals. Both are idle in July, 1897. One is said to belong to Mr. Wm. Showalter, the other to Mr. Patrick Dalton. Both have two open square kilns and manufacture common red brick by hand from the alluvium of the creek bottom.

At Ligonier Mr. John Robb operates a small brick yard, making common red brick. The brick are made from alluvium dug from the meadow on the south side of Loyalhanna creek. The clay is ground and tempered in an old style pug mill and the bricks molded by hand. The yard has been operated during the summer months for about twenty years.

About half a mile west of Ligonier is an abandoned brick yard that was operated by the Ligonier Fire Brick Co. during 1895 and 1896. The company started, it is said, with the intention of making fire brick, but the shale did not prove to be a fire-clay and they made some red brick, but it appears that even these were not a success and the works were abandoned.

There is a small brick yard at Mt. Pleasant said to belong to Mr. J. P. Loud and operated by Mr. Charles Hays. No particulars are at hand concerning it further than that it does not do a very extensive business.

IN THE YOUGHIOGHENY VALLEY.

Connellsville.—Soisson & Schlosser started a brick yard about one and a half miles south of Connellsville in November, 1896, where they make building and paving brick and some pressed bricks for fronts. They use a stiff-mud wire-cut machine, with a capacity of 8,000 per day. They have used clay from several beds near the works and are now (July, 1897) using surface clay obtained in the yard.

Mr. Jos. Stafford has operated a small brick yard about half a mile southeast of Connellsville. It is not in operation this year (1897). The material used as shown in the pit was three to four feet of surface clay and four feet or more of soft, dove-colored fissile shale.

Bird & Fancher started a brick yard along the Baltimore and Ohio Railroad a half mile below the Connellsville depot, in the summer of 1897, and burned three kilns of common red brick. The material used was a river deposit of clay and sand containing numerous boulders. The bricks were all made by hand from the material mixed in the old style pug mill, run by a horse.

Layton.—The Layton Fire Clay Co. at Layton station, make large quantities of buff building brick, besides fire brick and paving brick. (See Layton, under fire brick. Chapter V.)

West Newton.—Mr. John F. Caruthers has manufactured red brick at West Newton for eighteen years. The yard is on the west side of the railway track about half a mile below the West Newton station. The material used is the alluvium from the river bank, which is worked to a depth of eight or ten feet, in a few places fifteen feet or more in depth. The bricks are molded in a soft-mud machine which molds six bricks at once. The capacity is given as 10,000 per day but the works are only operated about two months in the year.

About two miles below West Newton on the east side of the railway track is the brick works formerly operated by Funk, Grantham and

Humphrey, but since May, 1897, by Mr. T. A. Humphrey. The bricks are made by machinery, having a capacity of 20,000 per day. The material used is a mixture of clay and shale.

A section of the quarry shows:

1. Surface clay, 3 to 5 feet.
2. Limestone, 4 to 5 feet.
3. Shale, rusty brown, black and gray, 6 to 8 feet.
4. Flagstone, 8 to 10 feet.

All of the material is used, numbers 1 and 3 used for brick, number 2 is burnt into lime and number 4 is used for flagstone.

There is a small brick yard using the alluvium of the river bottom about half a mile below Dawson, on the west side of the Youghiogheny river. It was formerly operated by Mr. Thomas Williams and is now said to be owned by Mr. P. G. Smith. It is only operated at irregular intervals.

UNIONTOWN, FAIRCHANCE AND SMITHFIELD.

Uniontown.—There are two brick yards at Uniontown, both making red brick. John N. Brownfield has operated a brick yard here for fifteen years and manufactures common red brick, all machine made, the works having a capacity of 10,000 per day. The bricks are burned with natural gas. The clay is dug from the surface and while he only works a thickness of about six feet it extends much deeper. He ships bricks to all parts of the coke regions.

The other Uniontown yard, which is operated by J. V. Williams & Co., has been in operation about 50 years: by J. V. Williams & Co. since March, 1897; by J. V. Williams alone for 28 years, and before that time by his father. They manufacture red building brick only and have a capacity of 25,000 per day. The clay used is a bluish sandy clay, weathering a reddish brown, and is dug from a bed about 14 feet thick. It is underlain by 14 inches of iron ore, underlain in turn by about 12 feet of blue clay. The clay is crushed and carried on a belt to the brick machine. The bricks are molded on a soft-mud machine which molds six bricks at a time. They are loaded on cars at the machine, which are first run into the drying tunnel and thence to the kiln to be burnt, where they are burnt with natural gas. The simple up-draft kilns are used.

Fairchance.—There are two brick yards in operation at Fairchance, one just started and the other 15 years old.

The Fairchance Brick and Tile Co. (Laughery & Densmore), are now (July, 1897), burning their first kiln. Their yard is between the Pennsylvania and the Baltimore and Ohio Railroad tracks, about 200 yards north of the railway station. They use an auger stiff-mud machine and a steam repress said to have a capacity of 15,000 per day.

They have had considerable delay by the breaking of the machinery. They make red brick only, using clay hauled in by wagon. The clay pit was not visited.

The Fairchance Lumber and Brick Co. (owned by Mr. Martin, of Pittsburgh; J. N. Erskine, foreman), operates a brick yard more than a mile northeast of Fairchance, at the base of Chestnut Ridge. They have a tramway from the works to the railroad. The yard has been in operation five years at its present location and ten years previously at another location in the vicinity. They have a capacity of 350,000 to 400,000 per month and make both building and paving brick. This is the first season they have made paving brick, the previous trade being wholly in building brick, largely dry-press building brick of fine quality that commands a good price. Their clay is mined from a bed of soft clay about nine feet in thickness, which is said to be underlain by seven feet of harder clay that is not used because it is harder, hence more difficult to work. Coal from the coking region west of the railway is used for fuel.

There is a small brick yard, apparently not now in operation, at Hutchinson station, and another along the railway between Fairchance and Uniontown. Mr. A. J. Hayden is now starting a small brick yard on the east side of the railway near Smithfield station. The material used is yellow surface clay, which is mixed in an old style horse-power pug mill and molded by hand, then placed in the sun to dry and finally burnt in an open kiln.

Other parties are said to have burned brick in the vicinity of Smithfield, but no other yards are in operation at present.

THE RED BRICK INDUSTRY IN THE MONONGAHELA VALLEY.

Nearly all of the brick yards in the Monongahela valley make only common red brick and their markets are largely confined to the valley between Brownsville and Pittsburgh. Those in Allegheny county are described by Mr. Affelder in Chapter VIII.

Monongahela City.—J. T. Conlin has been manufacturing common red building brick at Monongahela City for 25 years. For 12 years his yard was on the old pike near town, but for the past 13 years he has been working on the west bank of the Monongahela river about half a mile below the railway station. The material used is the alluvial deposit on the river bank. The capacity of the yard is 5,000 bricks per day. He ships some by rail and some by river, as far as Hazlewood and Duquesne, but most of the product is marketed at Monongahela City.

About 200 yards south of Mr. Conlin's brick yard is another that was first started by Mr. Ford and afterwards operated by Mr. Leidy, but since the death of Mr. Leidy about three years ago the yard has been idle.

Charleroi.—The Charleroi Brick Co. has been making red brick at Charleroi for five years. Their works are situated about half a mile north of the town on the west bluff of the Monongahela river, and have a capacity of 20,000 per day. The markets are along the Monongahela division of the Pennsylvania railway, and they have so far been crowded with orders. The bricks are all common machine-made red brick, no repress brick. The material used is a mixed red and yellow clay quarried on the river bluff near the works. A section of the present quarry face shows:

Surface clay, 3 to 5 feet.
Shelly sandstone, 4 to 10 feet.
Yellow clay, 4 to 5 feet.
Red clay, 15 to 20 feet.

The red clay used at this point outcrops in a number of places in the vicinity of Charleroi. There is a fine exposure of it in the little valley just south of the town.

Analysis of red clay and gray shale from south side of Charleroi.

	Red clay. Per cent.	Gray shale. Per cent.
Silica,	56.32	51.12
Alumina,	21.44	24.60
Iron oxide,	9.92	10.49
Loss on ignition,	6.73	6.59

Despite the marked difference in color and structure of these two materials, it will be noticed that they have a very similar composition. As is customary, the iron was determined as ferric, but not proven so. In No. 2 it is probably nearly all the ferrous iron and in the other the ferric. Both are rich enough in clay base to make a good strong brick, and both are too high in fluxes to make a good vitrified product. In comparing the two one would naturally infer that the red clay had a much higher percentage of iron than the gray, whereas the analyses show it to contain even less.

Fayette City.—About half a mile below Fayette city on the east side of the Monongahela river on the P. & L. E. R. R., the Dinsmore brothers have been manufacturing red brick since 1892. They also make a few fire brick. The brick are machine-made (soft mud), dried by steam in the drying tunnel, and burned in the open top up-draft kiln. Capacity 10,000 per day. The markets are mainly local, but they ship as far as Elizabeth.

The red brick are manufactured from shale obtained from the quarry on the hill above the works, where it is shoveled into a chute which conveys it into the works. The fire brick are made from the clay parting, the "horseback," in the Pittsburgh coal seam.

Section of the strata at Dinsmore Bros'. shale quarry.

	Feet.
Shale quarried for brick,	35
Shale, not quarried, partly concealed,	20
Pittsburgh coal seam and clay parting,	9
Shale,	10
Limestone and shale,	10
Shale,	8

It is only the upper part of the shale that is utilized, but the supply of shale is practically unlimited. The accompanying photo shows the structure of the shale in the quarry, Fig. 36.

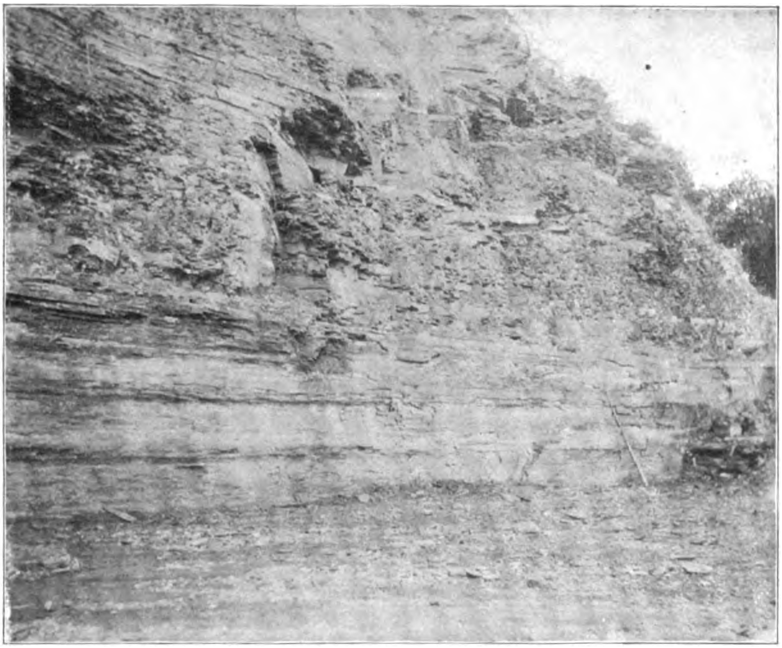

Fig. 36. View of shale quarry.

California.—F. H. Martin has manufactured red brick in California for 25 years. The yard is situated on the west bank of the Monongahela river nearly half a mile south of the railway station. The bricks are made by wire-cut machine, which has a capacity of 40,000 per day, but the actual output is much below this. The bricks are burned in an intermittent 3-chambered kiln, which was erected this year (1897), previous to which they were burnt in rectangular up-draft kilns. The 3-chambered kiln while still in the trial state is said to have given good satisfaction in the three kilns already burnt in it. The markets are mostly local. He makes repressed bricks, but the greater part of the output consists of the common red bricks.

The material used is the alluvium from the river bank which is drawn up an incline into the works by the engine.

There is a small brick yard near New Geneva and another near Greensboro, where small quantities of red brick have been manufactured for local usage, but the yards have not been operated for a number of years.

Paving brick industry.—The paving brick industry in western Pennsylvania is not at all commensurate with the fire brick or building brick industry. The following companies make paving brick in limited quantities along with other classes of brick: Jos. Soisson Fire Brick Co., Connellsville; The Layton Fire Clay Co., Layton; The Kittaning Clay Mfg. Co., and the Kittanning Brick and Fire Clay Co., both at Kittanning; The Fallston Fire Clay Co., Fallston; The Burl Fire Brick Co., Black Lick; Kountz Bros. Harmarville; Park Fire Clay Co., Rochester; Hiram Swank's Sons, Johnstown; Dunbar Fire Brick Co.; Eureka Fire Brick Works, Mt. Braddock; Fairchance Lumber & Brick Co.; Kuhn and Schaeffer, Hyde Park; Blatchford, Meeds & Co., Barking; Reese, Hammond & Co., are about to begin the manufacture of paving brick at Bolivar as this goes to press. The Pittsburg Clay Mfg. Co., at New Brighton did manufacture large numbers of paving brick a few years, but are making none now.

None of these companies manufacture paving brick alone, but only along with other kinds of brick. With most of them paving brick is purely a side issue and receives but little attention. With two of these, however, Kountz Bros. and Park Fire Clay Co., it is their principal business. The first of these is described in the following chapter; the second would give no information concerning their works.

A great many paving bricks are used in numerous towns of western Pennsylvania, and their use appears to be increasing rapidly, but many of them are shipped in from Ohio and West Virginia. Further mention of the paving brick industry of this portion of the State may be made in a future publication after the subject has been further investigated in other localities.*

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*Time did not permit a general description of the paving brick industry, as was done with the fire brick and building brick.

CHAPTER VIII.

THE CLAY INDUSTRIES OF ALLEGHENY COUNTY.

By William L. Affelder.

GENERAL STATEMENT.

The brick industry of Allegheny county has increased with wonderful rapidity during the past few years, until at the present time there are more than 50 brick yards in the county, almost half of which have begun operations during the present decade. A marked change has also occurred in the method of manufacture, for all the yards, with but few exceptions, have abandoned the hand mold and horse-power pug mill, and have adopted more modern and more economical steam-power machinery.

Of the brick machines in use, the Henry Martin soft-mud machine seems to be the general favorite, being used far more extensively than any other. Wire-cut auger machines, particularly the Freese and the Penfield are rapidly coming into prominence because of their large daily capacity and the ease with which they can be operated. The side-cut machine is used exclusively. An excellent example of the advantages of a wire-cut machine may be seen at Booth & Flinn's works, Pittsburgh, where a Penfield machine with an automatic cutting table is in use. It makes between 175 and 200 bricks a minute,

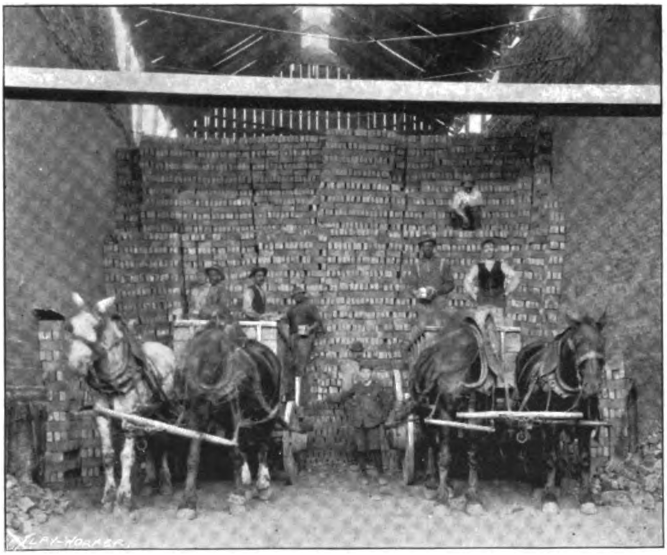


Fig. 38. Emptying a kiln.

cutting 18 at a time. The advantage in such a machine is not only the rapidity with which it turns out the brick, but also in the fact that only one man is required to operate it. A wire-cut machine also has some disadvantages, the principal one being that it often makes a very rough brick when shale is used, and that it requires a very plastic clay. The soft-mud machine makes an evener and more shapely brick, but it requires more men to operate it in proportion to its output than does the wire-cut machine.

About 200 kilns are used by the brick manufacturers in the county, almost all of which are constructed on the common open-top, up-draft principle. Down-draft kilns are very rare, less than 15 of them being in use. Booth and Flinn have the only continuous kiln used for burning red brick in the county. With very few exceptions, open air drying has been abandoned and more modern devices have been adopted. The dry floor is the common form of dryer in use, but tunnel dryers with either hot air or steam heat are also used extensively. Coal is used both for drying and burning, except in such regions where natural gas is cheaper. The manufacture of brick in this county gives employment to 1,500 men and boys, and the combined daily output of all the yards is slightly over 1,000,000 brick, valued at almost $6,000. Large as the output is, most of the material is common red brick. A fair percentage of the output consists of "stock" brick, which is a grade of brick good enough for building fronts, but the manufacture of pressed and paving brick is rather limited.

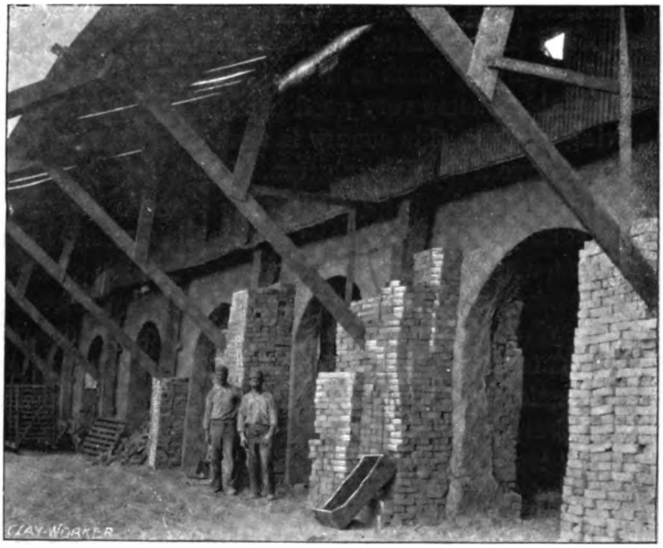


Fig. 39. Continuous kiln.

One of the strangest features of the brick manufacture in Allegheny county is the fact that so few paving brick are made. With the exception of the Kountz Brothers Co., of Harmarville, and Blatchford, Meeds & Co., of Barking, no company makes paving brick in any numbers What makes this all the more strange is the fact that large numbers of paving brick are annually imported into this county from Ohio and West Virginia. There are several reasons for this. The brick manufacturers believe that "a bird in the hand is worth two in the bush." They are able to make good building brick, and the demand for such brick is sufficient to keep the yards busy during the greater part of the year. They are content with making such brick instead of experimenting with the manufacture of paving brick. It requires greater care in mixing and burning to make a good paving brick, and the manufacturers are not anxious to contend with the numerous difficulties and unsuccessful attempts which they would at first be compelled to encounter. The trouble is not that the material for making good paving brick is lacking, for several companies have succeeded in making some very good brick. Another reason for not making paving brick in this county is that the imported ones which are now in use have a good reputation. They have been repeatedly used with success and their qualities are known, whereas the brick made in this county would first have to establish a good name before there would be a demand for them.

The vital reason is the one advanced at a recent meeting of the Western Pennsylvania Brick Exchange; viz., that it does not pay to make them. This reason seems rather strange at first, until it is given some consideration. Bricks are very unpopular for street paving in Pittsburgh, because they have failed to withstand successfully the heavy traffic to which they were subjected. Since most of the brick yards of the county—the largest ones at least—are situated near Pittsburgh, it would be necessary for the manufacturers to ship most of their paving brick. After paying freight on them, the profit, if there would be any at all, would be less than that which they could make from manufacturing building brick and selling them at home. The West Virginia and Ohio companies do not have to pay much more freight on their brick when they ship them into this county than the local manufacturers, because of the greater quantities which they ship. Besides, these companies which have both reputation and experience in their favor, can and do undersell the inexperienced Allegheny county manufacturers who have hardly gotten beyond the experimental stage. In brief, the manufacturers of this county are content with letting well enough alone, and with very few exceptions, restrict their attention to making common brick, which they can do with profit.

The manufacture of fire brick is not an important industry in this

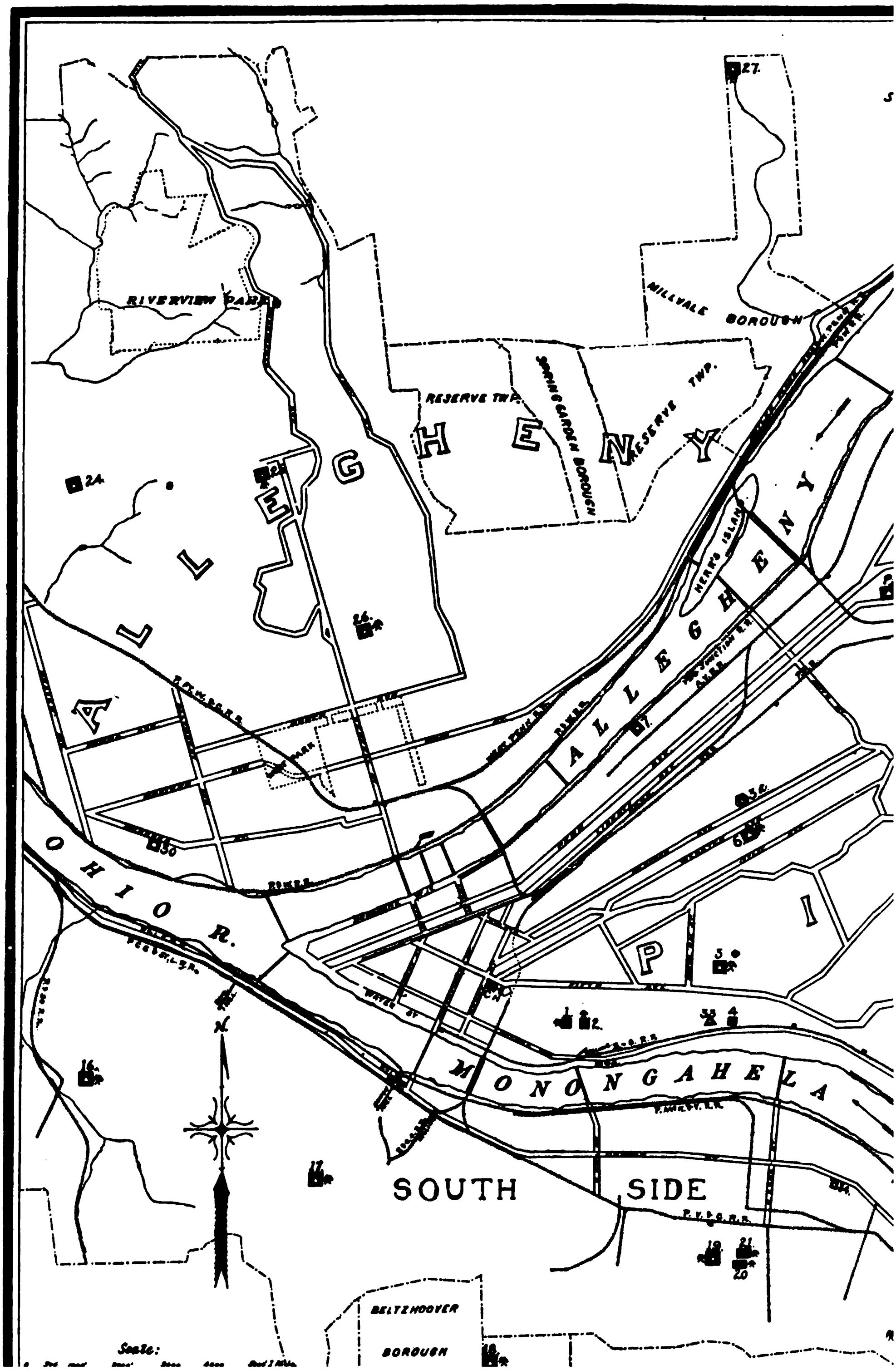
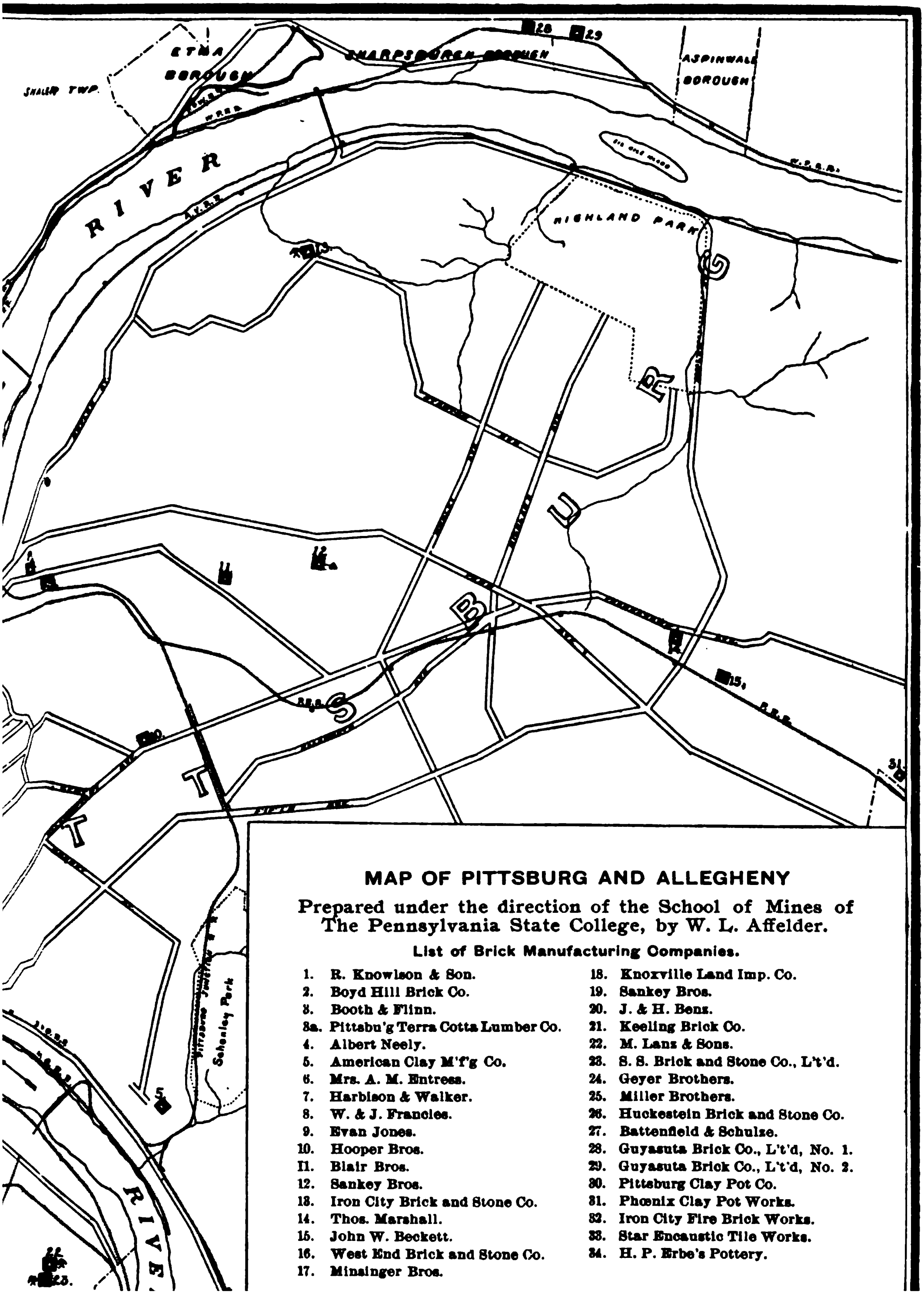

RIVERVIEW PARK
MILLVALE BOROUGH
RESERVE TWP.
SPRING GARDEN BOROUGH
RESERVE TWP.
A L L E G H E N Y
24
25
26
27
HERR'S ISLAND
A L L E G H E N Y
7
3
6
30
O H I O R.
P I
5
1
2
4
M O N O N G A H E L A
16
17
SOUTH
SIDE
19
21
20
BELTZHOOVER
BOROUGH
18
Scale:

PLATE VI.



MAP OF PITTSBURG AND ALLEGHENY

Prepared under the direction of the School of Mines of The Pennsylvania State College, by W. L. Affelder.

List of Brick Manufacturing Companies.

1. R. Knowlson & Son.
2. Boyd Hill Brick Co.
3. Booth & Flinn.
8a. Pittsbu'g Terra Cotta Lumber Co.
4. Albert Neely.
5. American Clay M'f'g Co.
6. Mrs. A. M. Entress.
7. Harbison & Walker.
8. W. & J. Francies.
9. Evan Jones.
10. Hooper Bros.
11. Blair Bros.
12. Sankey Bros.
13. Iron City Brick and Stone Co.
14. Thos. Marshall.
15. John W. Beckett.
16. West End Brick and Stone Co.
17. Minsinger Bros.
18. Knoxville Land Imp. Co.
19. Sankey Bros.
20. J. & H. Benz.
21. Keeling Brick Co.
22. M. Lanz & Sons.
23. S. S. Brick and Stone Co., L't'd.
24. Geyer Brothers.
25. Miller Brothers.
26. Huckestein Brick and Stone Co.
27. Battenfield & Schulze.
28. Guyasuta Brick Co., L't'd, No. 1.
29. Guyasuta Brick Co., L't'd, No. 2.
30. Pittsburg Clay Pot Co.
31. Phœnix Clay Pot Works.
32. Iron City Fire Brick Works.
33. Star Encaustic Tile Works.
34. H. P. Erbe's Pottery.

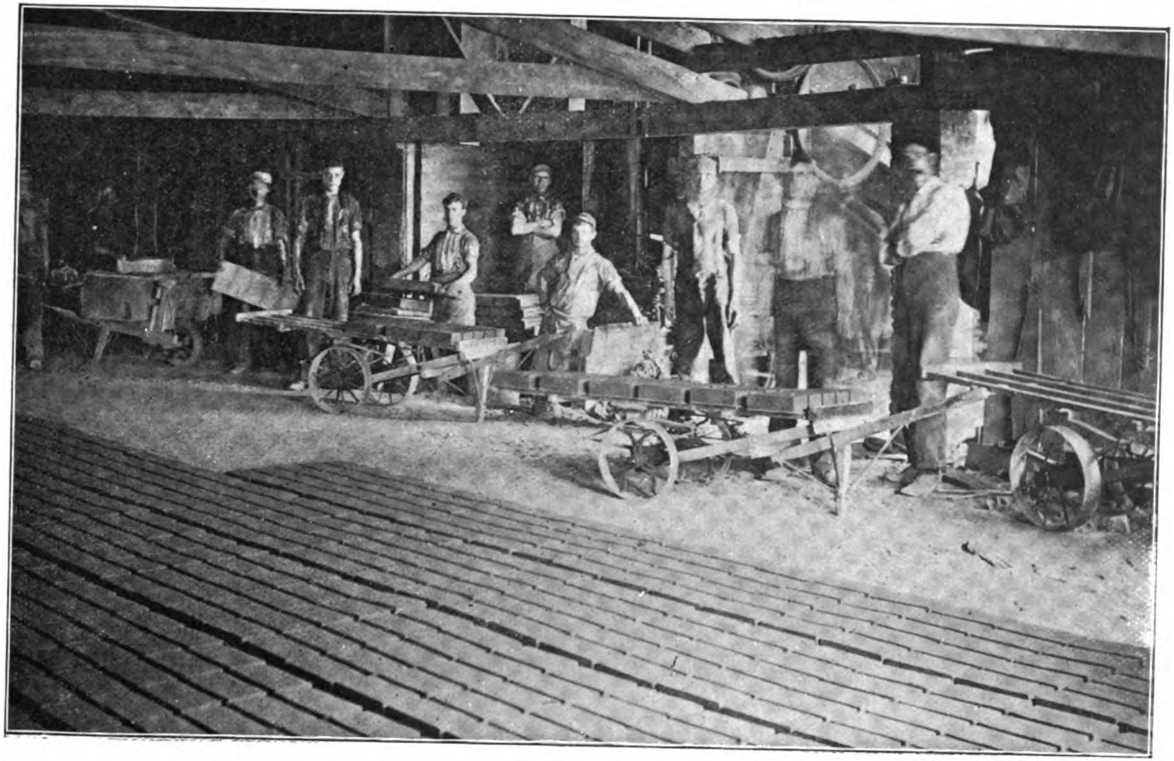


Fig. 40. A typical dry floor.

county mainly from the fact that good fire-clays do not occur in a sufficient abundance to be worked. The only fire brick works of importance in the county are those of Harbison & Walker, in Pittsburgh. Their clay is imported from localities outside the county. (See Chapter V.) Several companies have experimented with varied success, with "horse back" obtained from coal mines, making it into brick of fair quality.

The clays and shales of this county are used very little for industries other than the manufacture of brick. There are several clay pot works in the vicinity of Pittsburgh, but they use imported clays. The Star Encaustic Tile Co., of Pittsburgh, uses clay obtained at the works and imported clays. The Pittsburgh Terra Cotta Lumber Co. makes large quantities of terra cotta lumber for ornamentation and for fire-proofing, using only the shale and clay which occur at the works. Only one pottery—that of H. P. Erbe (Pittsburgh)—is located in the county. It is a very small one at which little other than earthenware is made.

Shipping facilities in the county are excellent, but the markets of the manufacturers are almost entirely local. Besides many railroads, there are four navigable rivers: the Ohio, Monongahela, Allegheny and Youghiogheny.

CLAYS AND SHALES.

The Lower Barren Coal Measures constitute by far the greater part of the surface rocks of Allegheny county. In fact, all of the northern half of the county with the exception of small areas of Upper and Lower Productive Measures, and about one-half of the southern part are covered by the Lower Barren formations.

SECTION OF THE LOWER BARREN MEASURES IN ALLEGHENY COUNTY.*

	Feet.
1. Pittsburgh coal bed,	..
2. Fire-clay.	3
3. Shale,	10
4. Limestone,	6
5. Coal bed,	1
6. Shale,	25
7. Limestone,	3
8. Shale,	10
9. Coal bed,	1.5
10. Limestone,	5
11. Connellsville sandstone,	60
12. Shale,	35
13. Coal bed,	1
14. Limestone,	4

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*Report KK, Second Geological Survey of Penna., p. 65.

	Feet.
15. Morgantown sandstone,	50
16. Clay,	9
17. Barton coal bed,	1
18. Shale,	30
19. Crinoidal limestone,	4
20. Shales and clays,	100
21. Coal bed,	2
22. Shale,	60
23. Black limestone and shale,	4
24. Shale and shaly sandstone,	35
25. Coal bed,	2
26. Shale,	30
27. Mahoning sandstone,	..
Total,	491.5

One glance at the above sections will show what an enormous amount of shale there must be in this county, for 349 feet, which constitutes about 71 per cent. of the total thickness of the series of 491.5 feet is shale, or shaly sandstone, and clay. At Pittsburgh, where 320 feet of strata of the Lower Barren Measures are exposed between the level of the Monongahela river and the outcrop of the Pittsburgh coal near the hilltop, almost all of the rock is shale. So enormous are the deposits of shale that the manufacture of brick can be carried on for centuries without materially diminishing the amount. Abundant as the shales are, they do not vary greatly in general characteristics. Almost all of them, with the exception of the very arenaceous ones, are well adapted to the manufacture of brick. All of them show evidence of iron to a greater or less degree. In some the prevalent state of the iron is the ferrous, while in others it is the ferric, but all of them are stained with ferric iron, especially after they have been subjected to the action of the atmosphere. By far the most common variety of the shale is the yellowish, slightly arenaceous one, which grades at the surface to a sandy clay and as the depth increases, to a more or less impure sandstone. Bluish shales are common in some localities. Some of them are so argillaceous and distinctly laminated as to look very much like slate, but the majority of them are shelly and readily disintegrate to small flakes. In color they grade from slate to bluish-gray. Recently M. Lanz & Sons, of Pittsburgh, have experimented with a bluish shale which occurs under the shale deposit from which they obtain their material for making red brick, and succeeded in making a buff brick of good color and quality for building purposes. Greenish shales containing much ferrous iron occurs less frequently than the blue. They are always badly discolored because of the action of the atmosphere. Red shales are not very abundant. Where they do occur they are generally disintegrated on the outcrop to a red clay.

Clays also occur quite abundantly in this county. They may be divided into four distinct classes: (1) residual clays or those resulting from the disintegration in situ of shales; (2) fire-clays and other interstratified clays; (3) alluvial clays; and (4) terrace clays. The clays of the first group generally have the same general characteristics as the shales from which they have been formed as far as chemical composition and color are concerned. In some instances, the clay is redder than the shale owing to the fact that the iron has become oxidized. The extent of such clays depends upon the amount of disintegration and erosion to which the shales have been subjected.

Fire-clays are not abundant in this county and where they do occur they are too impure to be used for making fire brick. In some localities these clays are used to advantage in making building or paving brick. At Harmarville, an excellent reddish-buff repressed brick is made from a ten-foot vein of such clay. The presence of a small amount of iron prevents uniformity in color and the brick are only adapted to paving. At Briggston a very hard building brick is made from an impure fire-clay mixed with hard shale.

Alluvial clays are used for making building brick at about ten per cent. of the yards. The clays used at these yards are obtained from the river flats which border on the Ohio, Allegheny, Monongahela and Youghiogheny rivers. In several instances the clay banks are so near the level of the present river beds that they are occasionally flooded. The principal advantage of such clays over shales and clays formed in situ is that they can be made into brick more economically. They are very easily quarried and are sufficiently homogeneous to make brick of uniform color. The alluvial clays can be hauled direct to the pug mill, whereas shales must first be ground and screened, which operations require machinery and entail considerable expense.

Terrace clays are quite abundant in the vicinity of the rivers, especially in and near Pittsburgh. They generally lie unconformably upon the underlying rock, and as their name implies, form terraces more or less parallel to the present river beds, but through erosion they have lost, to a considerable extent, their original form. The clays obtained from these deposits, like those of river flats, are generally sandy and contain gravel and boulders of various sizes. Terrace clays are used at a number of the brick yards in the county.

THE BRICK WORKS OF ALLEGHENY COUNTY.

a. Pittsburgh.

1. R. Knowlson & Son.* Office and yard, Vickroy st. near Magee st. —The brick yard of Knowlson & Son is among the oldest of those in the vicinity of Pittsburgh, having been in operation for about 50 years. The company employs 25 men and boys, who turn out 15,000 common red brick per day. The brick are dried on a dry floor and are burnt in four up-draft kilns, natural gas being used both for burning and drying. The market is entirely local.

The material used by this company is obtained from the same stratum as that used by the Boyd Hill Brick Co. (No. 2), consisting of a deposit of shale underlain by about 12 feet of good sandstone which is quarried for building purposes. The upper part of the shale deposit in Knowlson's quarry is distinctly blue in color. This, together with a dark red clay which occurs in a pocket in the shale, burns to a fairly good vitrified brick. Mr. Knowlson claims to have made a very good and durable paint of it.

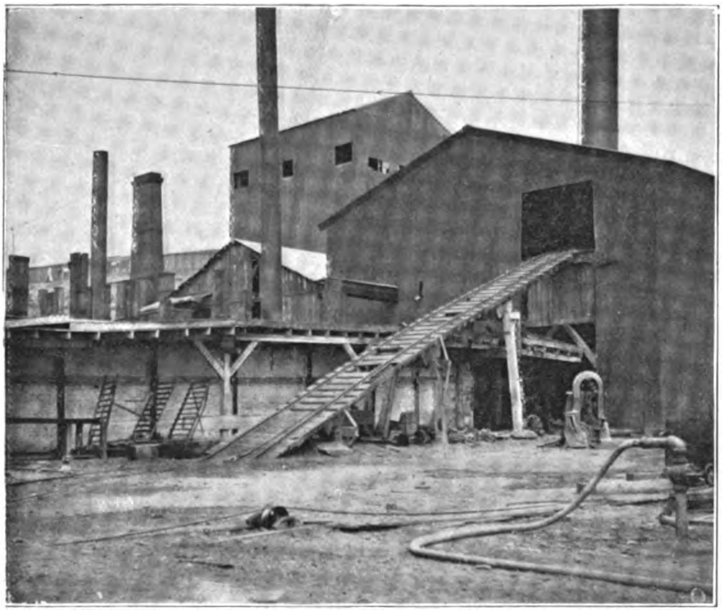

Fig. 41. A portion of a brick works, Pittsburg.

2. Boyd Hill Brick Co. Office and Yard, Corner of Vickroy and Magee Sts.—This company has been operating for 12 years. The daily output of 20,000 consists of common red and a few sidewalk

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*The consecutive numbering of the brick works agrees with the numbering on the accompanying map of Pittsburgh and Allegheny and in table in Chapter IX.

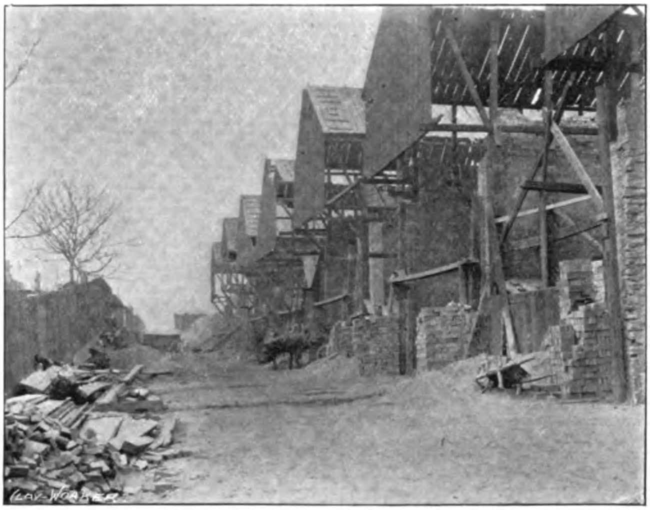

Fig. 42. Some up-draft kilns, Pittsburg.

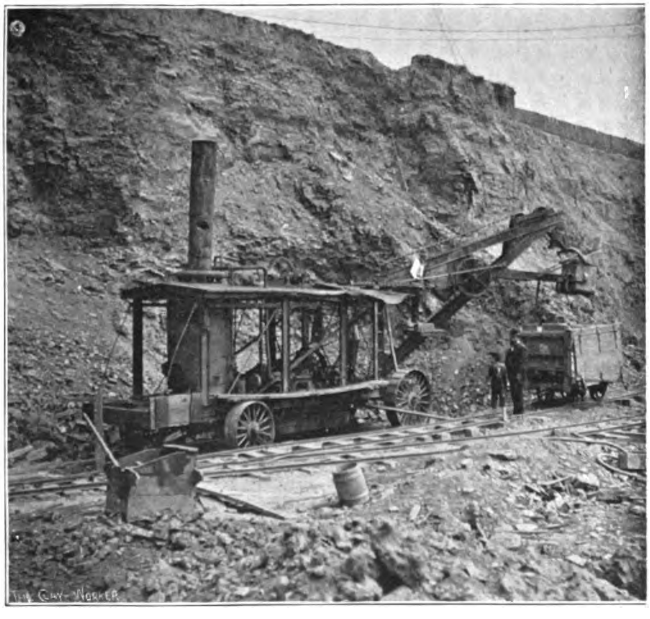

Fig. 43. Shale and clay quarry, Pittsburg.
Showing the method of mining clay with the steam shovel.

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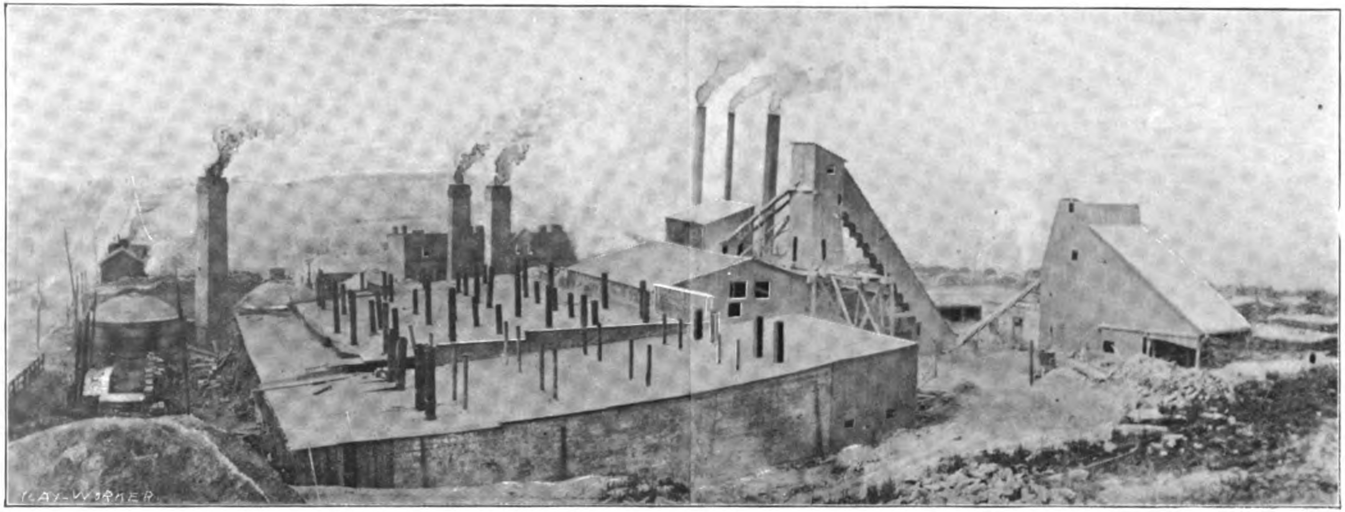

Fig. 45. Birds-eye view of a terra cotta works, Pittsburgh.

paving brick. They are dried in hot-air tunnel dryers and are burned in four up-draft kilns. The market is entirely local.

The clay and shale used by this company are obtained in an old sandstone quarry at the works. The stone, which is a good blue sandstone about 12 feet thick, has been exhausted except at the extreme western end of the quarry. Overlying this stone is a bed of yellowish, arenaceous shale about 25 feet thick, which becomes less arenaceous and more laminated towards the top. As the quarrying progressed from east to west, this shale was stripped off, was thrown behind, and has subsequently disintegrated to a five-foot bed of yellowish brown clay. The pit formed by quarrying the sandstone has also been partially filled with yellow clay hauled from excavations made at different places in the vicinity. This foreign clay, together with the disintegrated shale and the shale above the sandstone, are mixed and made into brick. The quarry is still worked for stone, but the supply will be exhausted at an early date.

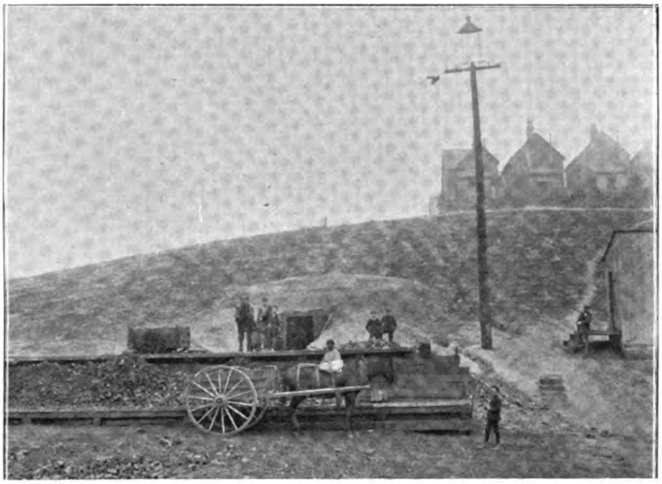

Fig. 44. Entrance to coal mine, Pittsburg.

3. Booth & Flinn. Office, 1942 Forbes st.; Yard, Ruch's Hill, head of Lombard st.—Booth & Flinn have been making brick for 8 years and now operate the largest and best equipped yard in Allegheny county. One hundred and eighty men turn out 125,000 brick per day, five per cent. of them being stock brick, and the remainder common red. Two stiff-mud, wire-cut machines are used, one cutting 18 and the other 12 bricks per cut. The bricks are dried in steam tunnel dryers and burned in nine up-draft kilns having a combined capacity of 4,000,000 brick and a continuous kiln consisting of fourteen chambers each holding 18,000 brick. Booth & Flinn's market includes all sections of Pittsburgh and Allegheny.

The shale occurs apparently at about the same horizon as that on Boyd Hill.

Section of the shale and clay at Booth & Flinn's.

	Feet.
Yellowish, disintegrating shale and clay,	20
Red shale with interstratified yellow clay,	30
Blue sandstone,	20

The lower part of the red shale is decidedly arenaceous. The crevices in the sandstone are filled with veins of calcite. All of the material is utilized. The sandstone is used for building stone and the waste is ground in with the shale for brick material. The shale is mined with a steam shovel which loads it into the tram cars in which it is transferred to the grinding pans.

On the hill 100 feet above the brick works, the company has an opening into a six foot coal seam (Pittsburgh Coal Bed), from which the fuel is obtained for operating the works.

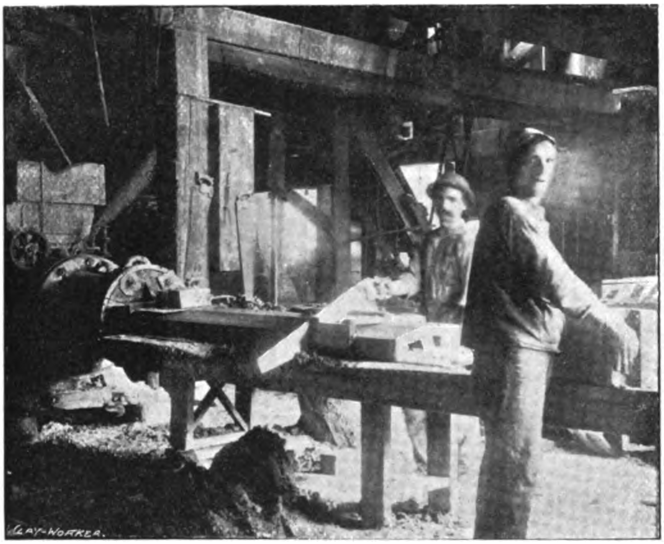
CLAY-WORKER.

Fig. 46. Cutting tile.

3a. Pittsburgh Terra Cotta Lumber Co. Office and Yard, 2400 Bedford ave.—This company manufactures the only terra cotta made in the county, and besides operating a large plant in Pittsburgh operates one at Port Murray, N. J. They turn out from 30,000 to 40,000 tons of material a year, which is shipped to many points in the eastern states and as far west as Houston, Texas.

The bottom of the bank from which the clay and shale used are obtained, consists of 15 feet of iron stained, bluish shale, which rapidly crumbles and disintegrates on exposure to the air. This shale is overlain by 15 feet of laminated yellowish shale which is so arenaceous that it might be called a shaly sandstone. Near the top of the

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bank the shale has weathered to a six foot bed of sandy clay, in which there is an occasional outcrop of shale. All of the material with the exception of the hardest sandstone is ground in dry pans, screened, and mixed with almost an equal quantity of saw dust in the pug mill. It is then molded to any desired shape in a Freese auger machine, is cut by means of a handsaw to pieces of desirable length, and is then

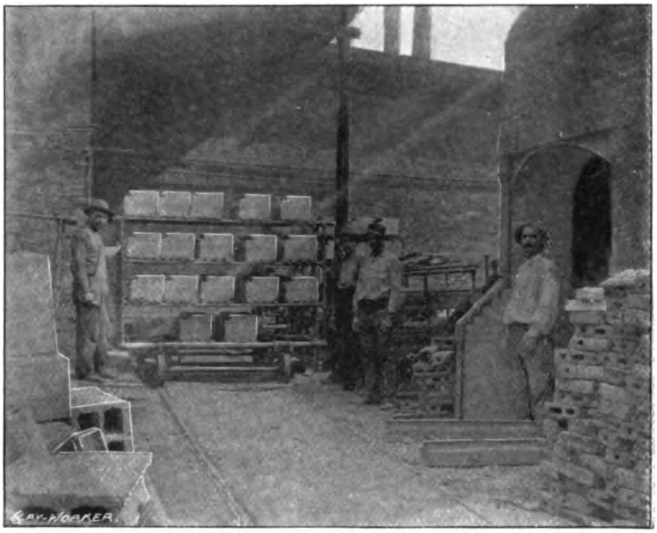

Fig. 47. En route to the kilns.

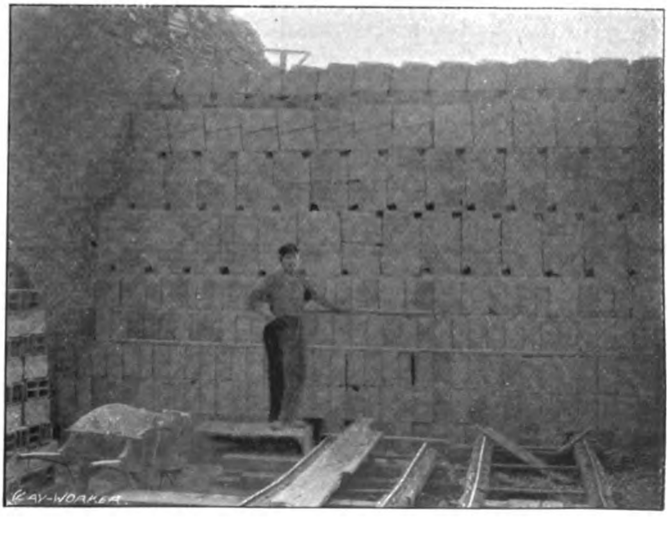

Fig. 48. Setting a kiln.

dried and burned in small round kilns. Mr. James O. Handy of the Pittsburgh Testing Laboratory analyzed a sample of the shale used and found it to contain:

Analysis of shale used by the Terra Cotta Lumber Company.

H^2O and organic matter,	7.517
SiO^2,	57.537
FeO,	5.797
Al^2O^3,	20.127
$CaCO^3$, $MgCO^3$, Alkalies, by difference,	9.022

4. Albert Neely. Office and Yard, corner of Tustin and Jumonville streets.—Mr. Neely makes common red brick by hand from clay hauled to his works from cellars and other excavations in the neighborhood. The works have now been in operation for almost 25 years. Five men are employed. The daily output is 5,400 common red brick, which are burned in three up-draft kilns. The market is entirely local.

5. American Clay Manufacturing Co. Office and Yard, Frazier street, near Griffith street.—The yard of this company has been operated for one year by the present company, previous to which time it was operated by Benney & Co., for three months. The daily output consists of 30,000 common red brick which are dried in steam tunnels and are burned with natural gas in three up-draft kilns which have a combined capacity of 550,000. The market extends throughout Pittsburgh and Allegheny. The company has a private siding from the Pittsburgh Junction Railroad.

The quarry of the American Clay Manufacturing Co., 200 feet long and from 15 to 40 feet in height, is in a hill situated west of Schenley Park. It consists of:

Sandy yellow clay, 3 feet.
Thinly bedded arenaceous shale, 8 feet.
Poor sandstone, 2 feet.
Clay, 30 feet.

The clay forming the bottom of the quarry is very hard and compact, and is of excellent quality. It is decidedly irregular in color owing to the action of the atmosphere upon the iron which it contains, but the prevailing color is reddish brown. The clay is exceptionally free from sand.

6. Mrs. Annie M. Entress. Office and Yard, Webster and Lawson streets.—Mrs. Entress' brick yard has been in operation since 1882. The daily output is 20,000 common red, stock, and sidewalk paving brick, which are dried on a dry floor and are burned by means of natural gas in three large up-draft kilns. The market is in Pittsburgh and Allegheny.

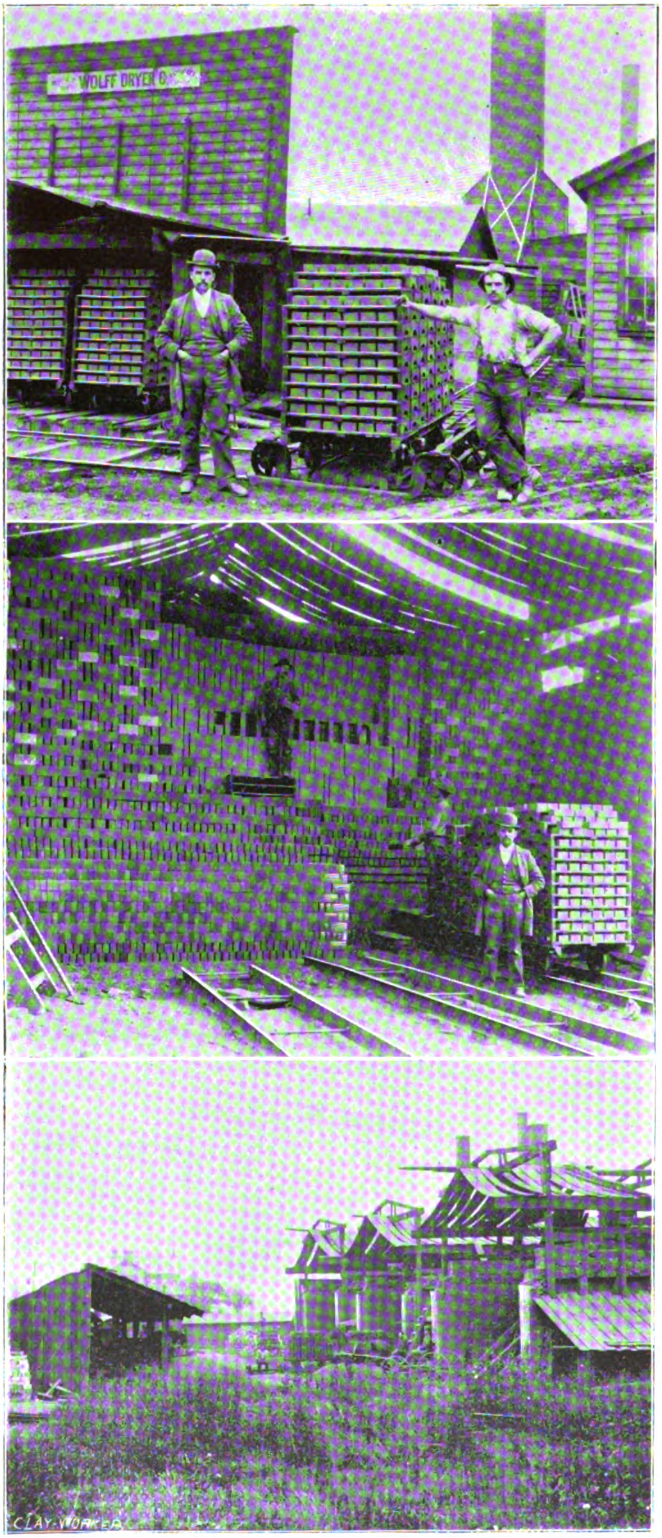

Fig. 49. Views of yard, East End, Pittsburg.

The clay and shale quarry consists of an opening 100 yards long and 30 feet high. At the bottom is a dark blue shale five feet thick, very arenaceous and containing mica flakes in considerable abundance, especially at the base where the shale grades into a dark gray sandstone. Above the blue shale is a yellowish shale which is only slightly arenaceous, except within ten feet of the top where there is a thin bed of sandstone, which again grades into a yellowish shale as the top of the quarry is neared, but the shale has almost entirely disintegrated to a yellow clay. Very little of the stone is suitable for building purposes.

7. Harbison & Walker. Office and Works, corner of Twenty-second street and A. V. R. R.—See Chapter V.

8. W. & J. Francies. Office and Yard, Corner of Liberty Avenue and Thirty-fourth street.—The Francies Brothers have been making brick since 1894, previous to which the yard was managed by other companies for 15 years. The daily output is abot 20,000 common red, stock, select, and sidewalk paving brick per day. The bricks are dried on a dry floor with the use of coal slack for fuel, and are burned with natural gas in four up-draft kilns, the total capacity of which is a little over one million. The market is entirely local.

The shale and clay quarry worked by this company is about 75 yards long and 25 feet high. The top of the quarry consists of old river terrace deposits. Though this deposit is several hundred feet above the present bed of the rivers, the terrace is very marked and can easily be traced for some distance along both sides of Liberty avenue. There is a thickness of six feet of sandy clay and cobble stones, varying in size from small pebbles to boulders weighing two or three hundred pounds. The clay in this terrace deposit is quite sandy but makes good brick. No use is made of the cobbles. Underlying the terrace deposit is one foot of dark red clay which is quite persistent in this neighborhood and can be easily traced over a considerable area. The red clay is underlain by a bed of shale more or less disintegrated near the top to a variegated clay, but the lower part of the deposit is blue, iron-stained shale distinctly laminated.

9. Evan Jones. Office, Carnegie Building; Yard, Liberty Avenue and Thirty-sixth street.—Mr. Jones operates a brick yard across Liberty avenue from Francies' yard, and uses clay and shale which are exactly similar in all respects to the material used at Francies' yard. Four up-draft kilns and a dry floor are in use.

10. Hooper Brothers. Office and yard, Bellefield and Centre avenues.—Hooper Brothers have been making brick for seven years and are now making 15,000 common red, stock, select, and sidewalk paving brick per day. The brick are dried on a dry floor, heated by means of coal, and are burned in three kilns of 200,000 capacity each, by means of natural gas. The brick are all sold in Pittsburgh.

This company owns fifteen acres of a gently rising hill, directly back of the works on which is located their present quarry, the opening being about 200 feet long and 18 feet high. The upper 8 feet consist of very sandy yellow clay containing a considerable amount of very arenaceous shale, especially near the bottom. This shale does not occur regularly, but projects at different parts of the clay bed. Beneath this clay and shale bed is a five-foot bed of iron stained, exceedingly arenaceous shale, grading into a shaly sandstone which is in horizontal layers varying from a few inches to one foot in thickness. It is underlain by five feet of clay, yellow and slightly shaly at the top but devoid of shale below the middle. All of the material exposed with the exception of the hardest and most arenaceous shale, is used in making brick, which are burnt quite hard and well adapted to sidewalk paving.

11. Blair Brothers. Office and yard, Edmond street near Liberty avenue.—Blair Brothers have been operating their brick yard for twelve years but machines have not yet been introduced, the grinding being still done by horse power and the molding by hand. The daily output is 16,000 common red and stock brick. Natural gas is used both in the dry floor and in the five kilns. The market is local.

The material used by this company consists entirely of clay, obtained from a six-foot bed of yellowish terrace clay, which is rather sandy and shows no traces either of lamination or of gravel. The company has on hand a considerable amount of yellow clay which has been hauled to the works from neighboring streets when they were graded.

12. Sankey Brthers. Office, 2101 Carson street, S. S., yard, Atlantic near Penn ave.—These works have been operated by Sankey Brothers for the last two and a half years, previous to which time they were managed by Mr. A. E. Wentzell for two years and by Mr. Miller for 12 years. The daily output consists of 15,000 common red and stock brick, the two kinds being made in almost equal numbers. The bricks are dried in a tunnel dryer, and burned by means of natural gas in four up-draft kilns of 275,000 capacity each. The market is principally the East End.

The company uses clay obtained from a clay pit at the works and from another situated on the opposite side of Atlantic avenue. The clay of both pits is the same, consisting of 8 feet of slightly sandy clay upon which rests about one foot of gravel. The formation is undoubtedly the remains of an old river terrace. The gravel formation is very marked in the pit at the works, but is absent in most parts of the other pit. The prevailing color of the clay is yellow, but large irregular patches of it are gray. It is easily quarried and requires very little grinding.

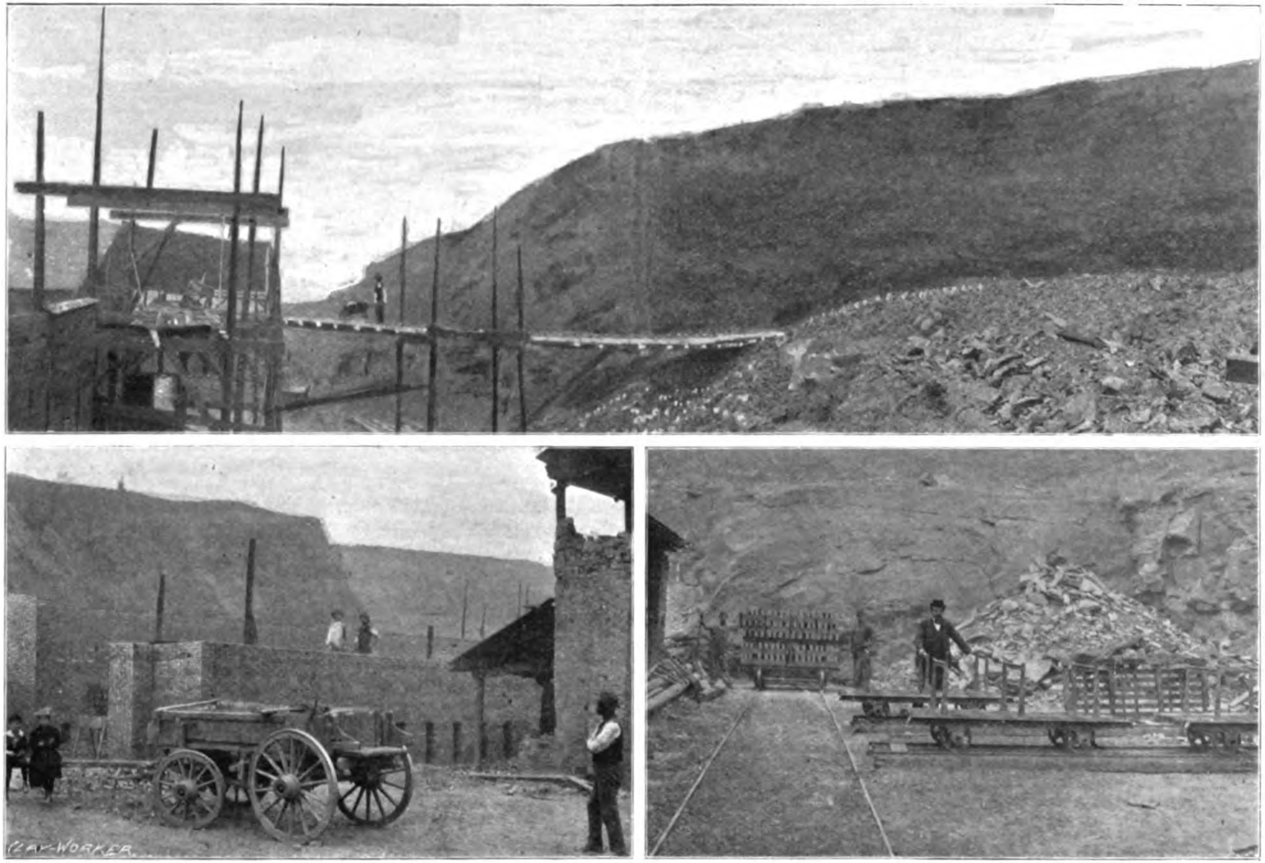

Fig. 50. Brick and stone quarry and works, Allegheny County.

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13. Iron City Brick and Stone Co. Office and yard, Stanton ave. and McCandless st.—The Iron City Brick and Stone Company has been in operation for 6 years, manufacturing common red brick, which are dried in a steam tunnel and burned in four up-draft kilns, each holding 300,000 brick. Natural gas is used for fuel and for burning the brick. The daily output is about 30,000 and the market is local.

The company owns 13 acres of land at the works. The present quarry face is about 100 yards long and 45 feet high. The upper 12 feet consist of yellow clay and shale, interlaminated with greyish clay. The upper 3 feet consist of sandy clay free from shale. Beneath this the shale grades into a soft sandstone which again changes rapidly to shale. Below this top formation of 12 feet is a 12-foot bed of hard, unlaminated clay, which is of excellent quality and entirely free from sand. The first foot of this clay is bluish, underlain by a foot of yellow clay, followed again by blue, becoming more and more red toward the bottom, with a foot of blue clay at the base. Yellow clay occurs in irregular patches in the red clay. This clay rests upon 20 feet of thick-bedded sandstone of good quality. All the material above the stone is made into brick, and the sandstone is quarried and used for building purposes.

14. Thos. Marshall. Office, 5020 Cypress st.; yard, Kelly st. near Torrence st.—This yard has been operated by Mr. Marshall for one year, and by Mr. A. E. Wentzell for two years. The daily output is 6,700 hand-made red brick, which are dried on a dry floor and are burned in three up-draft kilns of 185,000 capacity each. Coal is used for all fuel. The brick are sold in the immediate vicinity of the works.

Behind the works is a ten-foot deposit of clay covering a limited area. It is of terrace origin, cobbles of various sizes being very numerous. The upper two feet of clay are very sandy, but the remainder is entirely free from sand. The clay consists of alternate layers of yellow and gray. It is easily ground in an old-fashioned, horse-power, pug mill.

15. John W. Beckett. Office and yard, corner of Hamilton and Dallas aves.—These works have been operated by Mr. Beckett for 20 years and now have a daily output of 15,000 brick, three-fourths of which are common red and the remainder stock brick. They are dried on a dry floor, and burned in four up-draft kilns, each holding 300,000 brick. Natural gas is used both for drying and burning. The brick are disposed of in the vicinity of the works.

The clay bank from which the material for making brick is obtained is situated across Hamilton avenue from the works. It is in the same terrace formation as Mr. Marshall's clay bank. The top of the formation is 15 feet above the street, and it is only being worked to the street level. The clay is of excellent quality, being hard yet easily worked and being almost free from sand and gravel. The upper half of the clay is yellowish, but the lower part is brownish. Within two feet of the bottom there are several layers of almost white sand, each about three inches thick.

b. South Side.

16. West End Brick and Stone Co. Office, 121 Wabash ave.; yard, 35th Ward.—The works of this company have been in operation three years, and at present the daily output is 16,000 common red brick, which are dried on a dry floor and burned in three up-draft kilns whose combined capacity is 650,000. Coal waste is used for all fuel. The brick are sold principally in the West End district of Pittsburgh.

The works are situated on Saw Mill run at the bottom of a hill of considerable height. The company obtains its material for making brick directly behind the works. The lowest visible formation is twelve feet of unlaminated yellow clay, which on account of its hardness breaks off in large irregular masses. Above this are three feet of red clay more distinctly laminated than that below it. Upon this clay rest 15 feet of thin-bedded sandstone which grades at the top into an arenaceous shale. A little further up the hill, this shale reaches a depth of more than 20 feet. The next formation is ten feet of good, red clay, which is in the form of clay at the surface, but is presumably shale further in the hill. Overlying the clay is a bed of 35 feet of excellent, thick-bedded, blue sandstone, which is quite calcareous; so much so in fact that it makes good material for macadamizing.

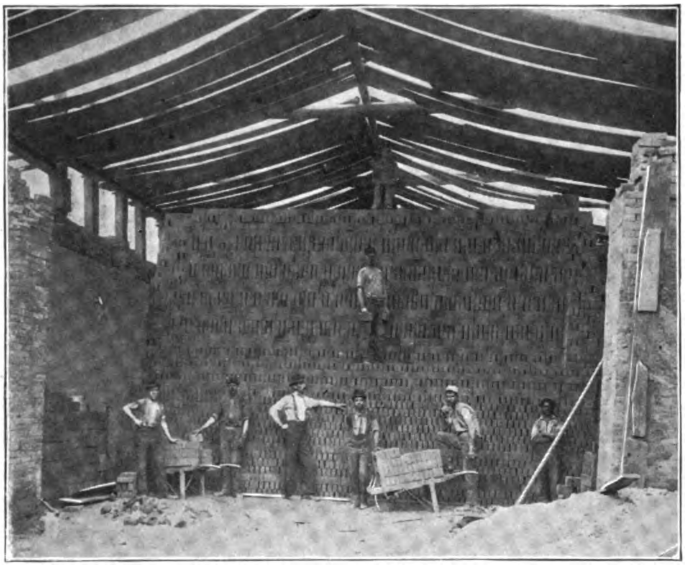

Fig. 51. Setting a kiln.

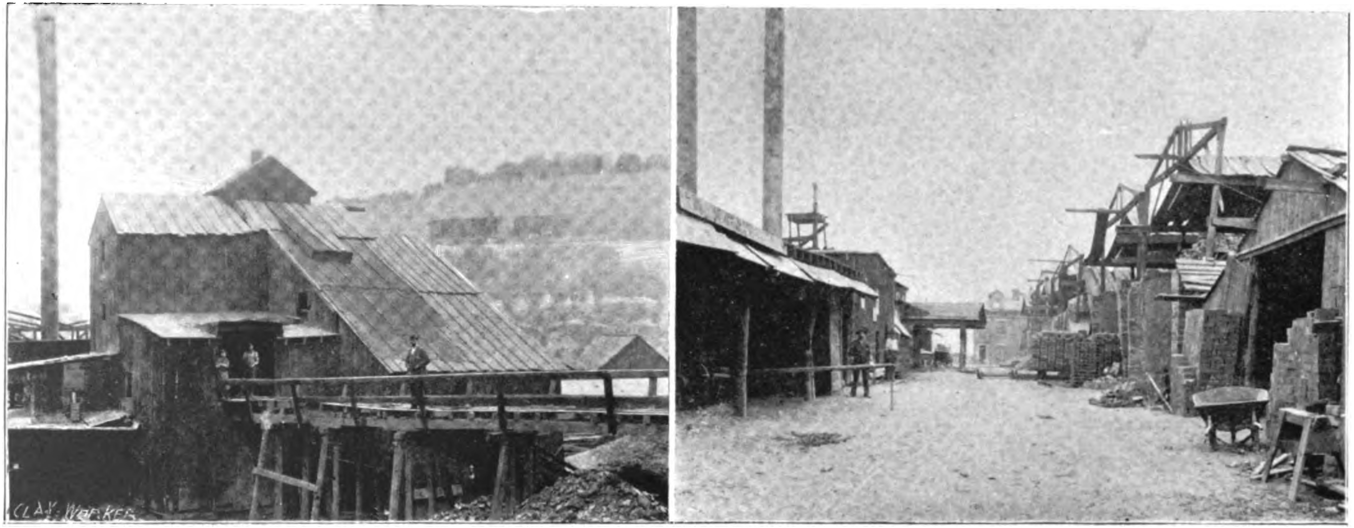

Fig. 52. A portion of a South Side works, Allegheny County.

The stone is quarried extensively by the company. Shale and clay overlie this sandstone, the thickness increasing with the distance up the hill.

The portion of the hill exposed consists of:

	Feet.
Shale and clay,	..
Sandstone	35
Red clay,	10
Shale,	20
Thinly bedded sandstone,	15
Red clay,	3
Hard clay,	12

The shales and clays above and below the sandstone are used in the manufacture of brick. At present, the bulk of the material used is stripped from above the stone, in order to allow the quarrying to progress. The shale and clay in this vicinity are inexhaustible as they constitute the bulk of the hill. There are several other points farther up the run where the same bed of sandstone is quarried by other parties.

17. Minsinger Brothers. Office and yard, Prospect st., Mt. Washington.—Minsinger Brothers have been manufacturing brick for 12 years, turning out 10,000 brick per day. The brick are dried on a dry floor and burned in three up-draft kilns of 200,000 capacity each. Natural gas is used for all fuel. The brick are sold in the Mt. Washington district of Pittsburgh.

Minsinger's quarry is the only one in or very near Pittsburgh situated above the Pittsburgh coal bed. The quarry face shows a bed of impure limestone overlain by four feet of very sandy clay, grading at the top to six feet of thinly-bedded sandstone. This sandstone is overlain by four feet of laminated, arenaceous shale, which, together with the sandy clay overlying the limestone, is made into brick. The remainder of the quarry consists of a 20-foot bed of gray sandstone overlain by 5 feet of clay, which is rendered worthless by the large percentage of lime present. The stone is being quarried extensively.

18. Knoxville Land Improvement Co. Office, 86 Knox avenue. Knoxville; yard, Knoxville.—The works of this company, which have now been operated for 16 years, give employment to 17 men and boys, who manufacture 7,500 common red and 2,500 stock brick per day. Natural gas is used for fuel in the four kilns. The combined capacity of the kilns is 900,000 brick. The brick are sold in and about Knoxville.

This company obtains its clay and shale from a quarry in a gentle slope, situated directly behind the works. Beneath about 20 feet of very poor sandstone, upon which rests three feet of sandy clay, are ten feet of very arenaceous shale. At the western end of the opening the sandstone and shale thin out and disappear, and in their stead is a five-foot bed of yellowish and grayish clay, underlain by 15 feet of greasy shale, solid and somewhat arenaceous at the bottom, but becoming more clayey and less sandy towards the top. The sandstone increases in thickness and improves in quality farther in the hill.

19. Sankey Brothers. Office, 2101 Carson street, S. S.; works, South Eighteenth street.—These works are the oldest ones on the South Side, having been in operation for more than 30. years. The present company has had charge of the works for 16 years. The daily output is about 13,000 common red and 7,000 dry pressed brick, which are dried in steam tunnel dryers and burned by means of natural gas in six up-draft kilns, each having a capacity of 230,000. Some special shapes are made, the number depending on the demand. Most of the brick are sold in Pittsburgh, but some of them are shipped via the Pittsburgh, Virginia and Charleston Railroad and the Pittsburgh and Lake Erie Railroad.

The material used by this company is obtained from an extensive opening in the hill at the works. The upper five feet are yellow clay, and the remainder of the bank consists almost entirely of soft, clayey shale containing a great many segregations of impure limestone which are crushed and used on the roads in the neighborhood. The shale is about 30 feet thick and is underlain by three feet of alternating gray and yellow clay, which is underlain by greenish shale, containing a number of thin layers of red shale. All the shale is badly disintegrated, but traces of horizontal lamination are still very marked. All of the material exposed, with the exception of the limestone, is used in making brick. Beneath the shale deposit is very good sandstone which is being quarried.

20. J. & H. Benz. Office and yard, South Twenty-first street and Quarry Road.—The daily output of this company is 15,000 common red brick. They are dried in a Sach Radiated Heat Dryer, and burned with coal in four up-draft kilns of 250,000 capacity each. The works have been in operation for 15 years. The market is principally in the South Side, but some bricks are shipped via the Pittsburg, Virginia and Charleston Railroad and Pittsburgh and Lake Erie Railroad.

The material used by this company is similar to that used by Sankey Brothers, being at the same geological horizon. Owing to the fact that the quarry is farther down the hill than Sankey's, the clay and shale above the sandstone are not so thick.

21. Keeling Brick Co. Office, 2014 Josephine street, South Side; yard, Quarry Road, S. S.—This company has been manufacturing brick for 10 years and turns out 15,000 common red brick per day. Five kilns, each having a capacity of 280,000 brick, are used. The brick supply a local market and are shipped via the Pittsburgh and

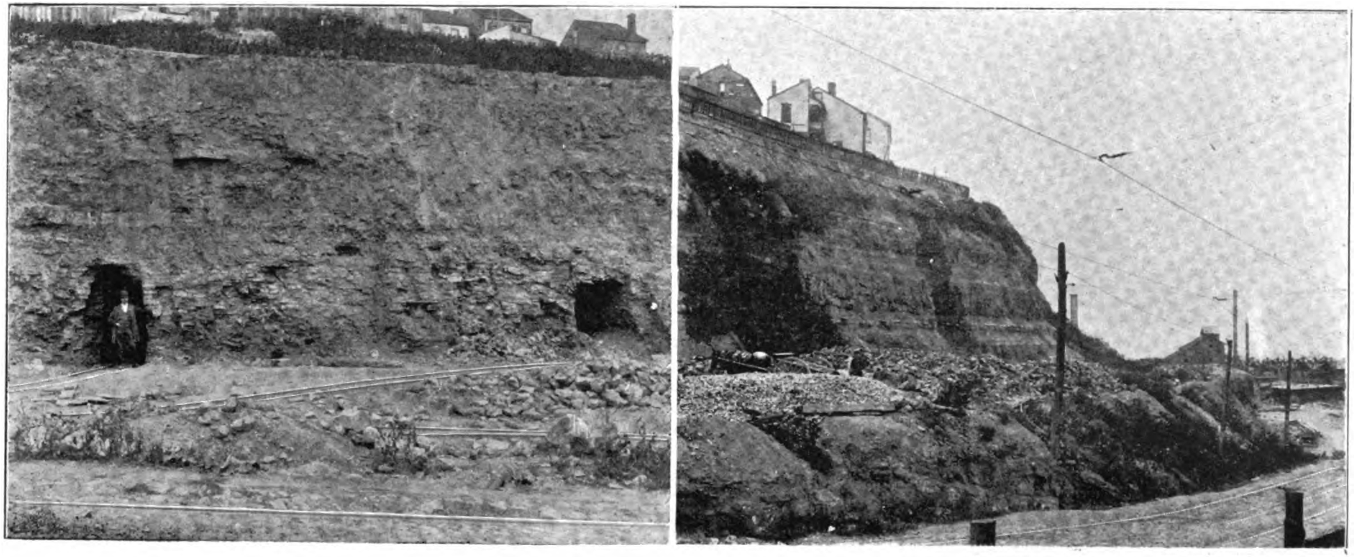

Fig. 53. A South Side quarry, Allegheny County.

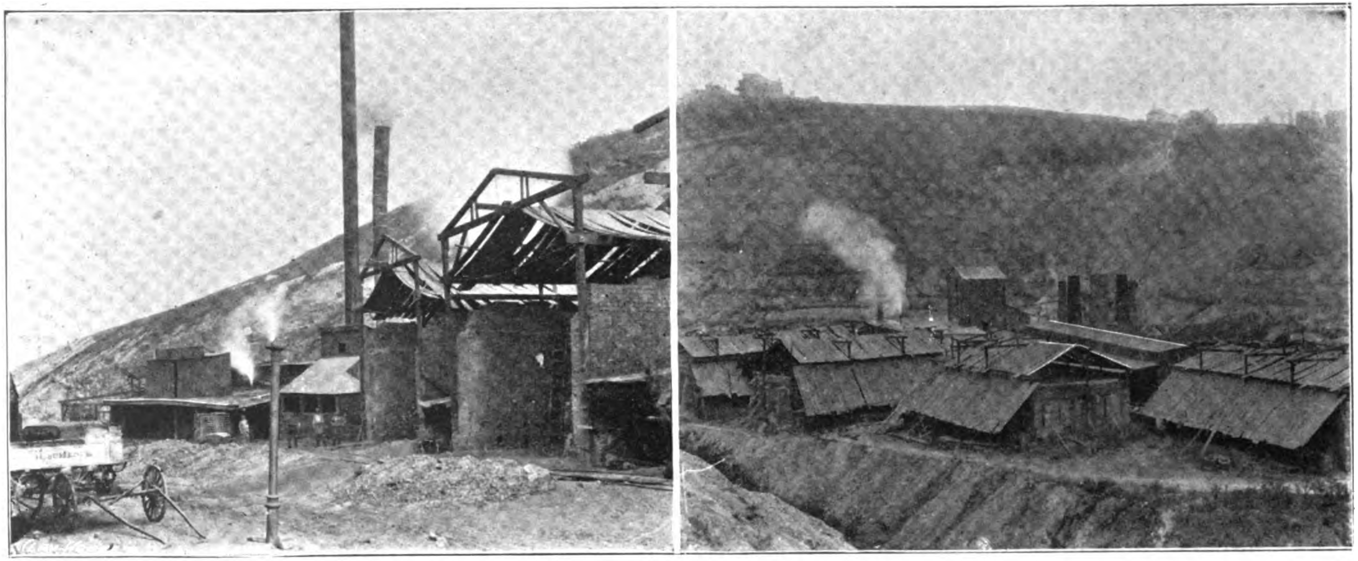

Fig. 54. Views of brick yard.

Lake Erie Railroad and the Pittsburgh, Virginia and Charleston Railroad.

The quarry of this company is situated on the hillside directly below that of Sankey Brothers. It is beneath the sandstone which forms the bottom of Sankey's and Benz' quarries. The brick are made from a 25 foot bed of shale which grades both at the top and bottom into sandstone, which is quarried and used as a building stone.

22. M. Lanz & Sons. Office, S. Twenty-ninth and Carson streets; yard, head of S. Thirty-fourth street.—This company manufactures about 20,000 brick per day, 20 per cent. being stock, 20 per cent. dry pressed, and the remainder common red. A few buff building brick have also been made from a bluish clay which occurs at the bottom of the quarry. The bricks are dried by steam and burned in five up-draft kilns, each having a capacity of 275,000, and are fired by natural gas. Although the company's market is almost entirely local, a few brick are shipped to points within ten miles of Pittsburgh via the Pittsburgh, Virginia and Charleston Railroad which passes directly below the works.

At the top of the bank from which the shale and clay are obtained, is a ten-foot deposit of good sandstone which is being quarried by the company. Beneath this sandstone are ten feet of sandy clay containing fragments of impure sandstone. This clay grades into a compact, laminated shale thirty feet thick, which has a greenish gray color near the top, but it becomes decidedly blue as the bottom is approached. Under the shale, which forms the present bottom of the quarry, is a blue, calcareous clay which crumbles to small nodules on exposure to the atmosphere. The company has been experimenting with this material and has found that it can be made into very good buff brick.

23. South Side Brick and Stone Co. Limited. Office and yard, head of S. Thirty-third street.—This company has been engaged in the manufacture of common red and stock brick for seven years. The daily output of 17,000 is burned in five up-draft kilns, each having a capacity of 250,000. The steam tunnel system of drying is used. The market is almost entirely local, but some little shipping is done via the Pittsburgh, Virginia and Charleston Railroad.

The quarry of this company is on the hill lying south of the Monongahela river directly above M. Lanz & Sons' quarry. The top sandstone of Lanz' opening forms the bottom of the S. S. Company's quarry. This sandstone, here about ten feet thick, is of excellent quality and is quarried extensively. Upon it rests a six-foot bed of distinctly laminated red shale which is rather arenaceous where it is in contact with the stone. The material making up the remainder of the exposure is 25 feet of shale, upon which rest five feet of sandy clay. The shale is yellowish in color, but is interlaminated with red. About ten feet below the top of the quarry is a seam of coal a few inches thick.

c. Allegheny.

24. Geyer Brothers. Office and yard, Woodland avenue near New Brighton Road.—This company is one of the few in the vicinity which has not yet adopted steam machinery. Hand molds and the horse-power pug are still used. The works have been in operation for ten years and give employment to ten men and six boys. The daily output of 7,000 brick is burned in three medium-sized, up-draft kilns. Both the dry floor and the kilns are fired with coal.

The clay bank of this company consists of a ten-foot bed of terrace clay deposited years ago by the Allegheny or the Ohio river. The clay is decidedly sandy, especially near the top, and is very easily worked. The upper two feet are light in color, but the remainder of the clay is brownish, the line between the two being decidedly marked.

25. Miller Brothers. Office and yard, Charles street.—Miller Bros. have been manufacturing common red brick for the past six years. The daily output is 25,000 brick, which are dried in steam tunnels and burned by means of coal in four up-draft kilns of 200,000 capacity each. The brick are all disposed of in Allegheny.

In the hill which is situated directly behind the works, is a large quarry of excellent sandstone about 18 feet thick. The fissures in the stone are filled with calcite which has been leached out of the overlying strata. Above the stone are two feet of sandy yellow shale, grading at the bottom into sandstone, and at the top into clay. The clay overlying the shale is 20 feet thick, consisting of very good reddish clay, bluish in spots and exceptionally free from sand. It is far more distinctly laminated than such clays generally are. The clay and shale used in making brick are in a sense by-products from the stone quarry, as it is necessary to strip them off in order to work the stone. The stratum of sandstone is very persistent, being quarried in a number of places in the immediate vicinity.

26. Huckestein Brick and Stone Co. Office, 37 Fairmount street; yard, Nunnery Hill.—These works, which have been in operation for the past 15 years, turn out 13,000 common red brick per day, which are dried on a dry floor and burned in three up-draft kilns, each holding 250,000 brick. Natural gas is used as fuel in both dry floor and kilns. All the brick are sold in Allegheny.

Besides using clay hauled from neighboring streets which are being paved, the company uses clay and shale stripped from above the sandstone in the quarry situated directly behind the works. The sandstone is 15 feet thick and is sufficiently good to warrant its being quarried for building purposes. Upon this rests irregularly laminated, arenaceous shale, which grades into 15 feet of good but somewhat sandy clay, containing an occasional streak of red clay.

d. Allegheny River Valley.

27. *Battenfield & Schulze.* Office, 73 Grant avenue, Millvale; yard, Millvale Borough.—These works have been in operation for but one year and eighteen thousand red brick are manufactured daily. The company has three up-draft kilns, each having a capacity of 200,000. The market is entirely local.

As at most brick yards in this region, the company owns a sandstone quarry and utilizes the overburden in the manufacture of brick. The sandstone is 35 feet thick, grading at the top into eight feet of good but rather sandy yellow clay. Below the stone are 30 feet of arenaceous yellow shale, especially arenaceous near its contact with the sandstone. About 20 feet below the sandstone, imbedded in the shale, occurs a two-foot bed of badly weathered limestone. The shale is all more or less disintegrated, and together with the clay above the stone can be made into good brick.

28 *and* 29. *Guyasuta Brick Co., Limited.* Office, Eighteenth street and W. P. R. R., Sharpsburg.—This company operates two brick yards, one situated near the office and the other about a quarter of a mile further up the railroad. The No. 1 yard has been operated by the company for one year and for four years by other companies. The daily output is 20,000 common red and stock brick, which are dried and burned with natural gas. The three up-draft kilns in use have a combined capacity of 675,000.

The No. 2 yard was leased a year ago from Wanner and Stein, by whom it had been operated for three years. The 20,000 brick manufactured per day are burned in three up-draft kilns, holding in all 475,000. The output of both works is sold in Sharpsburg and in Pittsburgh and Allegheny, the shipping being done on the West Penn R. R.

The two yards use exactly analogous material occuring similarly in both banks and consisting of a 12-foot bed of reddish to yellowish clay which rests upon 15 feet of yellow shale, which is worthless on account of being too arenaceous. The clay is presumably of alluvial origin, having been deposited by the Allegheny river before it cut its bed down to its present level.

35. *The Kountz Brothers Co.* Office and yard, Harmarville.—This company is the only one in the county which is very actively engaged in the manufacture of paving brick. The works have been operated for about five years. The daily output is 35,000 brick, consisting of vitrified paving, common red, and dry pressed brick in varying proportion. They are dried in steam and flue dryers and are burned in 7 down-draft kilns, six holding 175,000 each, and one having a capacity of 60,000. The company finds an extensive market for its brick, shipping via the West Penn R. R. to Pittsburgh and thence on the Pennsylvania R. R. as far east as Philadelphia.

The clay and shale quarry of this company is situated in a steep hill directly behind the works. All the formations lie horizontally and conformably upon each other. The upper ten feet consist of very slightly disintegrated shale, yellowish at the top, but dark brown at the bottom, underlying which is a five-foot bed of very poor sandstone, grading at the bottom into an underlying bed of reddish yellow, arenaceous shale, 12 feet thick. Below the shale is a six-inch seam of coal underlain by ten feet of iron-stained, blue clay. All the material thus far described, with the exception of the sandstone, is made into brick, but the exposed material below the blue clay is not made use of. This material consists of 20 feet of very arenaceous shale underlain by 15 feet of argillaceous shale. The blue clay is an impure fire-clay, which burns to a reddish-buff color, owing to the small percentage of iron present. The company has experimented considerably with this clay, but has not yet been able to obtain satisfactory results.

Section of Kountz' shale quarry.

	Feet.
Slightly disintegrated shale, ...	10
Poor sandstone, ...	5
Shale, ...	12
Coal, ...	0.5
Blue clay, ...	10
Arenaceous shale, ...	20
Argillaceous shale, ...	15

36. Blatchford, Meeds Brick Co. Office and yard, Barking.*—Like Kountz Brothers, this company is one of the few in the county who have ventured into the manufacture of vitrified paving brick, 4,000 of which are made daily. An equal number of common red, stock and re-pressed brick are also made. The brick are dried in a steam tunnel and are burned in three up-draft and three down-draft kilns, having a combined capacity of 600,000. All the brick are shipped via the Allegheny Valley R. R. to Pittsburgh and intermediate points.

The shale quarry consists of 10 feet of yellowish, arenaceous shale, overlain by seven feet of alternate layers of blue and yellow shale, which are overlain by eight feet of yellowish and six feet of blue shale. Overlying the blue shale, is a poor shaly sandstone which is too arenaceous for making brick. All of this shale used is very hard and is well adapted to the manufacture of hard and durable paving brick.

37. McFetridge Brothers. Office and yard, Hite Station.—At this yard, only common red brick are made, the daily output being 18,000,

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*Until recently this station was known as Johnston.

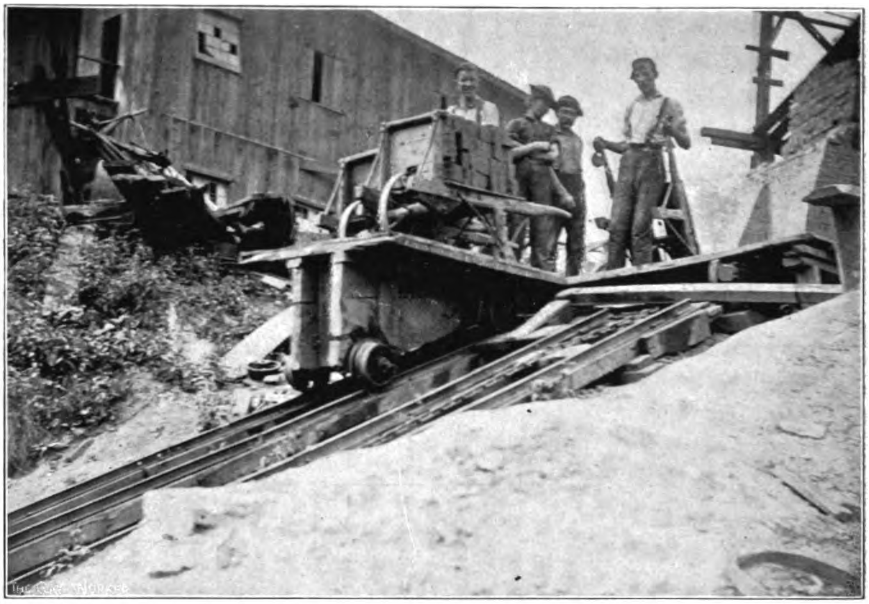

Fig 56. Transporting brick to the railroad cars.

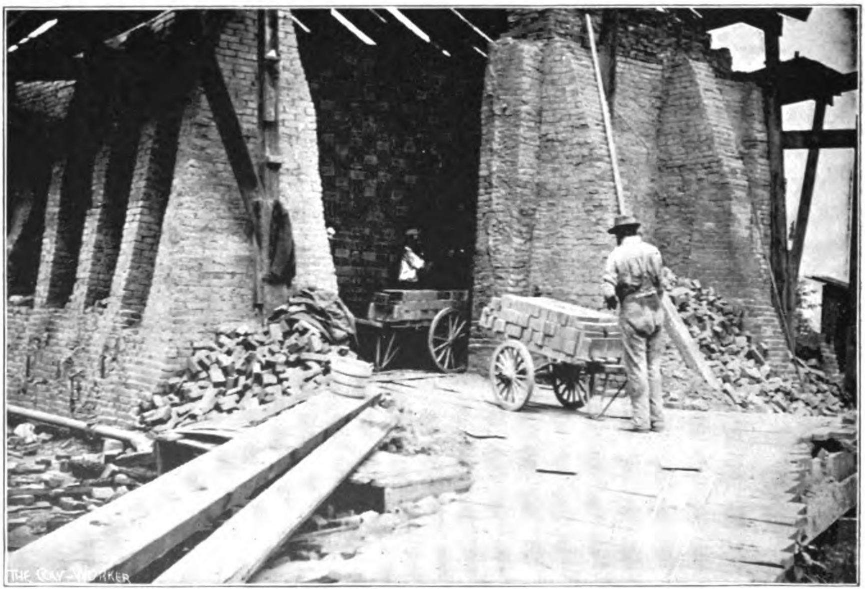

Fig. 57. Setting a kiln.

which are burned in four up-draft kilns holding 800,000 brick. The output is shipped via the West Penn R. R., principally to Natrona.

The shale and clay quarry is situated about 50 feet above the outcrop of the Freeport coal bed, the intervening material being arenaceous shale and poor sandstone. The material quarried consists of about 30 feet of yellowish and reddish shale, rather clayey in parts, especially near the top. The shale is divided into somewhat regular blocks by joint planes which extend into the hill perpendicular to the face of the quarry and to the bedding planes, making quarrying a very easy matter.

38. *Wittmer Brick Co.* Office, 12 Federal street, Allegheny; yard, Wittmer Station.—The yard of this company, which has been operated during the past thirteen years, is one of the largest in the county, its daily output being 50,000 common red brick. The brick are dried on an old style dry floor and burned in four large up-draft kilns, coal being used for all fuel. They are shipped via the West Penn R. R. to Pittsburgh and vicinity.

The quarry from which the material used is obtained is in a 25 foot bed of slightly sandy, yellowish shale mottled irregularly with red. The shale is distinctly laminated and is separated by a marked line from the 50 feet of exceedingly arenaceous and worthless shale which underlie it.

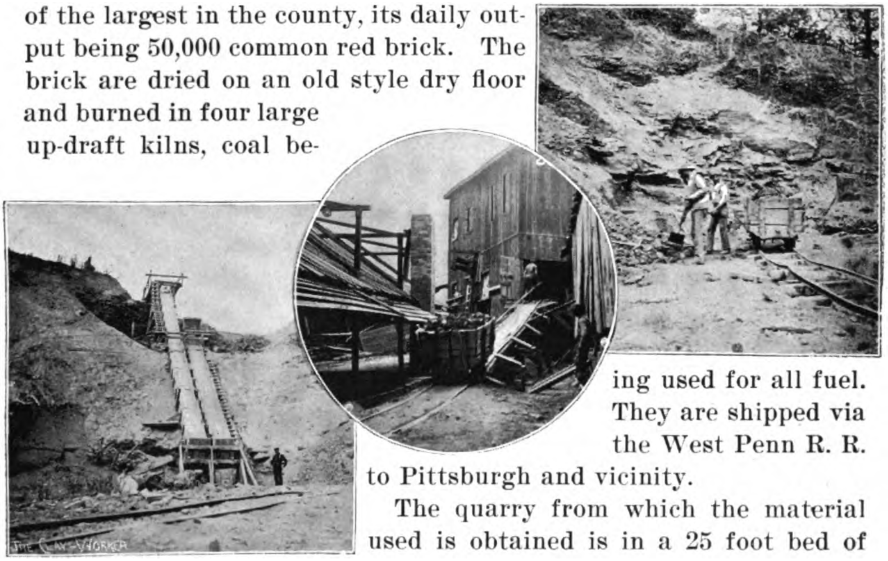

Fig. 55. Views in Witmer's yard.

e. Ohio Valley.

39. *Fort Pitt Stone and Brick Co.* Office, Carnegie; yard, Fort Pitt.—Up to the present time (Aug., 1897) the yard of this company has only been operated for a few weeks. Only one of the four kilns which are to be used has been completed. A steam tunnel dryer is already in use. The output, which the company predicts will be 25,000 common red brick per day, will be shipped to Carnegie, Washington, Pittsburgh and other points on the Pan Handle R. R.

Until recently, the company has only been engaged in quarrying limestone and selling it for macadamizing roads, but so much good clay and shale must be stripped off that this material is now being made into brick. The limestone is of excellent quality, seven feet thick, and in three distinct benches. The joint planes are also very pronounced, making quarrying very easy. It is underlain by a thin seam of poor coal, and overlain by six inches of thinly laminated, iron-stained, blue shale, which crumbles to small particles when exposed to the air for a short time, and by five feet of very sandy yellow clay, which contains some gravel. The Pittsburgh coal bed outcrops less than 30 feet above the limestone.

40. Carnegie Brick Works. Office and yard, Carnegie.—The yard of this company, which has been operated for the past five years, has a daily output of 10,000 common red brick, which are dried in a steam tunnel dryer and in the open air, and are burned in three medium sized up-draft kilns, coal being used for all fuel. The market is entirely local.

With the exception of Minsinger Brothers' yard in Pittsburgh, the yard of the Carnegie Brick Works is the only one in the entire county which obtains its material for making brick from a horizon higher than that of the Pittsburgh coal bed. On the road to the works, there is an excellent outcrop of the coal bed, about 50 feet below the clay bank. The latter consists of eight feet of hard, yellowish brown clay, containing irregular gray streaks, underlain by two feet of greyish clay. About two feet below the top of the bank, occurs an irregular band of gravel, which points strongly to the fact that the neighborhood was formerly submerged in the Ohio river, or in a stream which is now extinct.

41. Penn Brick Co., L't'd. Office and yard, Leetsdale.—The daily output of this company consists of 20,000 common red and stock brick, which are dried by means of natural gas and are burned with coal in five up-draft kilns, three of which have a capacity of 250,000 each. The market is almost entirely local, but some of the brick are shipped to points on the P., Ft. W. & C. R. R.

The clay used by the Penn Brick Co., L't'd, is obtained from an alluvial flat situated 200 yards from the Ohio river and at about the present high water mark. The clay is about eight feet thick, rather sandy and decidedly homogeneous in quality. It is soft and easily worked, making it well adapted to the soft-mud machines in which it is used.

42. Harmony Brick Co. Office and yard, Leetsdale.—This yard has been operated for the past nine years by the Economite Society, of Economy, Penna., prior to which time it had been operated by other companies for a number of years. The daily output is 20,000 common red brick, which are dried in a steam tunnel and are burned with both gas and coal in seven up-draft kilns, five of which have a capacity of 400,000 each, and the other two 125,000 each. Some of the brick are hauled to Sewickley, but the bulk of them are shipped by rail to points along the P., Ft. W. & C. R. R.

The yard of the Harmony Brick Co. is situated about three-quarters of a mile further down the Ohio river than that of the Penn Brick Co., and the clay banks of both companies are exactly similar in all respects. When the Ohio reaches its high water mark, it floods both the yard and the clay bank.

43. Pittsburgh Brick Co. Office, 644 Grant st., Pittsburgh; yard Briggston, P. & L. E. R. R. The yard of the Pittsburgh Brick Co. is situated about one hundred yards back from the Ohio river on the slope of the steep hill which forms the southern bank of the river at this point, on the main line of the P. & L. E. R. R. About 30,000 common red and dry pressed brick are made daily. They are dried in steam tunnels and are burned with coal in four medium-sized, up-draft kilns. The brick are shipped by rail to Pittsburgh and intermediate points.

The following table will best show the principal features of the quarry operated by the Pittsburgh Brick Co. All of the material with the exception of the ten feet of fire-clay, is in distinct horizontal laminae, and a better assortment of hard materials for making good, durable brick than is found here, could not be desired.

Quarry face of the Pittsburgh Brick Company.

	Feet.
Green arenaceous shale,	10
Blue argillaceous shale,	15
Coal,	.2
Fire-clay,	10
Hard blue shale,	10

f. Monongahela Valley.

44. J. K. & S. D. Mills. Office, 818 Main street, Braddock; works, Copeland Station.—Mills Brothers' yard has been in operation for only a few months (Aug. '97), and the equipment is far from being complete. A steam tunnel dryer has been erected, but no work has yet been done towards building kilns. The daily output of 10,000 will be sold in Braddock and vicinity.

The clay and shale used for making brick are the material which must be stripped from the 35-foot bed of grey sandstone which the company is quarrying. The shale grades from clay at the top into sandstone at a depth of 15 feet. The stone if of very good quality and is quite thickly bedded.

45. Keller & Milliken. Office and works, foot of 8th street, Braddock.—This yard, which has been operated by the present proprietors for three years, was previously operated by another company for several years. The daily output of 15,000 common red and stock brick are dried on a dry floor and burned in three up-draft kilns, coal being used for all fuel. The market is almost entirely local, but some shipping is done on the P. & L. E. R. R., the B. & O. R. R., and the P. R. R.

The clay bank from which this company obtains its clay is situated on the Monongahela river, considerably below the high water mark. The clay resembles all similarly formed river deposits, being a 15-foot bank of yellowish brown, somewhat sandy clay of homogeneous texture. It is very easily worked in a soft-mud machine.

46. J. R. Ward & Sons. Office, 817 Penn ave., Wilkinsburg; yard, Brinton.—The Wards have been operating this yard but one year, and make when running regularly, 10,000 common red brick per day. A dry floor of the ordinary type and three medium-sized, up-draft kilns are used. The market is principally local, but some shipping is done on the Pennsylvania R. R., from which a side-track runs to the yard.

The company is operating a sandstone quarry in the hill directly behind the works, and the stripping, consisting of 12 feet of grayish-yellow, arenaceous shale disintegrated to sandy clay at the surface, is used in the manufacture of brick. The quarry consists of about 50 feet of excellent, thick-bedded, gray sandstone which is quarried and shipped to points along the railroad.

47. J. M. Rumbaugh Brick Co. Offices, Greensburg and Wilkinsburg; yard, Pitcairn Station.—Next to Booth & Flinn, the daily output of the Rumbaugh company is the largest in the county, consisting of 50,000 common red and 10,000 dry pressed brick. They are dried on a dry floor and burned in five unusually large, up-draft kilns, coal being used for fuel. The market is along the Pennsylvania Railroad, between Pitcairn and Pittsburgh, all the shipping being done by rail. Large as the daily output is, only 40 men and boys are employed, which fact illustrates the advantage of having a yard equipped with good machinery.

The company's quarry is a 200 by 40 foot opening in the hill directly behind the works. The exposed section is as follows:

Yellowish laminated shale, 15 feet.

Dark blue shale, 5 feet.

Light blue clay, 8 feet.
Bluish sandstone, 2 feet.
Shale, bluish and reddish, 10 feet.

The blue clay burns to a buff color, but is not used alone. The sandstone is quarried and makes a good building stone. The bottom deposit of shale is variegated in color but blue prevails near the top, and red near the bottom.

48. Keystone Brick Co., Limited. Office and yard, Mathias avenue, near Riverton avenue, McKeesport.—This yard, which has been operated for the past five years, has a daily output of 10,000 common red and 5,000 stock brick, which are burned in three up-draft kilns of 180,000 capacity each. The market is almost entirely local and in Duquesne, but some shipping is done via the Baltimore and Ohio, Pittsburgh and Lake Erie and Pennsylvania railroads.

The quarry of this company is in a shale hill at the yard. Near the surface the shale has weathered to a reddish-brown clay, but beneath this the shale is distinctly laminated. It is blue, except where it has been exposed to the atmosphere for some time, the exposed parts being more or less red. The shale becomes more arenaceous as the depth increases.

49. Tube City Brick Co. Office and yard, Mathias avenue near Riverton avenue, McKeesport.—The yard of the Tube City Co. is situated near that of the Keystone Co. The daily output, consisting of 15,000 common red and 2,500 repressed brick, is burned in three up-draft kilns, each holding 225,000. The market is almost entirely local, but a little shipping is done by rail.

The shale and clay are obtained directly above that used by the Keystone Co,. but the shale has disintegrated to a laminated clay to a greater degree than further down the hill. Towards the top of the quarry the shale becomes so arenaceous that it cannot be used for making brick and grades into a very good sandstone, which is being quarried by the company.

50. Standard Brick Co. Office, 701 Fifth avenue, McKeesport; yard, Eighth Ward, McKeesport.—Fawcett Brothers, the proprietors of this yard, have been operating it for four years. The daily output consists of 10,000 common and 9,000 dry pressed brick, which are dried on a common hot floor and burned in two small sized, up-draft kilns. The market is entirely local.

The material used by this company is very much like that used by the Tube City Co., except that the reddish brown shale has disintegrated more extensively in the quarry of the former. The face of the quarry, which is about 175 feet long and 12 feet high, shows only occasional traces of the original shale, and the lamination is very indistinct. Although a great part of the iron has been oxidized to the ferric state, the material burns into a uniformly colored, durable brick.

51. Glassport Brick Co. Office, 515 Walnut street, McKeesport; yard, Pollock Station.—At this yard only common red building brick are manufactured, 15,000 of them being made daily. They are dried in a steam tunnel dryer and burned in three up-draft kilns of 220,000 capacity each. The market is local and in McKeesport. Shipping facilities are excellent, as the Pittsburgh and Lake Erie Railroad passes through the yard, and the Monongahela river is only a few hundred yards distant.

The clay and shale quarry is 100 feet long and about 20 feet deep, consisting principally of dark reddish shale, badly disintegrated to red clay, especially near the top. Several veins of yellowish clay, between six and eighteen inches thick, occur in the red clay. All of the material is easily worked and it requires but little grinding.

52. Monongahela Brick Works, Blair Station.—These works, which are owned by J. T. Chambers & Co., are situated between the Pittsburgh, Virginia and Charleston Railroad and the Monongahela river. The yard has been idle for more than a year and Mr. Chambers does not intend to resume operations. The yard is in very good condition, being equipped with both a soft-mud and a stiff-mud machine and five up-draft kilns, and the shipping facilities are excellent. The clay bank consists of an extensive river flat containing eight feet of good alluvial clay. It is below the high water mark.

53. A. M. Pierce, West Elizabeth.—Mr. Pierce's yard occupies a position exactly similar to that of the Monongahela Brick Works, and like the latter has not been in operation for several years. The equipment, consisting of an old-fashioned horse-power pug mill, molds for making brick by hand, a hot floor, and four up-draft kilns are all in very poor shape. The clay was obtained from the alluvial flat bordering on the river.

g. Youghiogheny Valley.

54. Christy Park Brick Works. Office and works, Christy Park Borough.—This yard has been operated for the past year by Mr. Oscar Dougherty, and by others for 12 years. Twelve to fifteen thousand common red brick are made daily, are dried on a dry floor, and are burned in two small up-draft kilns. The market is entirely local.

The clay bank is situated about 50 feet from the Youghiogheny river, in the flat bordering on the river. The clay is very sandy and contains a considerable amount of gravel.

55. C. M. C. Harper & Co. Office and yard, Boston.—This yard was operated from 1885 to 1895 by Kerr & Harper, and by the present company since 1895. Fifteen thousand brick, consisting of common red, stock, hand pressed and sidewalk paving are made daily. The brick are sold in McKeesport and at various points on the Monongahela river between Pittsburgh and Belle Vernon. Shipping is done via the Youghiogheny river and the Pittsburgh and Lake Erie Railroad, both of which pass the works.

The quarry, situated in a hill about one-fourth mile behind the works, consists of 15 feet of hard, somewhat arenaceous, laminated shale overlain by four feet of yellow clay and 12 feet of yellowish brown clay. The material is hauled to the yard in wagons.

56. Yough Brick Co. Office, 326 Fourth avenue, Pittsburgh; Works, Greenock.—At this yard 18,000 common red, buff, and sidewalk paving brick are made daily, all of them being dry pressed. They are dried on a dry floor and burned in four up-draft kilns.

The quarry consists of three feet of worthless blue, argillaceous shale, overlain by 15 feet of hard, compact, thinly laminated "soapstone." Three or four feet of sand, clay and gravel, the remainder of a former terrace of the Youghiogheny river, overlie the soapstone.

57. Greenock Brick Works, Greenock.—Mr. Peckman, the proprietor of this yard, has been manufacturing soft-mud bricks for 11 years. The daily output of the yard is 18,000 common red brick, which are dried in the open air and on a dry floor and are burned in four large, up-draft kilns. The brick are shipped via the Youghiogheny river and Pittsburgh and Lake Erie Railroad to points along the Monongahela river between Pittsburgh and Belle Vernon.

The clay bank is in a ten-foot deposit of yellow, sandy clay, situated in an old river terrace.

Summary of the Brick Industry of Allegheny County.

Capital invested:	
Figures sent in by 25 companies, ...	$1,115,500
Estimated for remaining 27 companies, ...	1,096,804
Total, ...	$2,212,304
Value of output for 1897:	
Figures sent in by 25 companies, ...	$551,904
Estimated for remaining 24 companies in operation, ...	489,971
Total, ...	$1,041,875

Total daily capacity, bricks,	1,066,000
Total number of kilns,	199
Average number of days in operation in 1897,	280.4

The kinds of machines in use are:

Martin soft-mud machines,	21
Penfield soft-mud machines,	4
Other soft-mud machines,	5
Penfield stiff-mud, wire-cut machines,	9
Freese stiff-mud, wire-cut machines,	7
Raymond stiff-mud, wire-cut machines,	1
Dry-press machines,	5
Repress machine,	1
Hand machines,	6
Total,	59

The estimate for the capital of the companies that did not report is based on the daily capacity which is known for all. We assumed that the capital of the companies that did not report would be in the same ratio to their daily output as the capital of the companies that did report would be to their daily output, and the estimate for the production for 1897 was proportioned in the same manner.

CHAPTER IX.

STATISTICS OF THE CLAY INDUSTRY OF WESTERN PENNSYLVANIA AND ANALYSES OF THE CLAYS.

Table I. List of the potteries and tile works.
Table II. List of the fire brick works.
Table III. List of the red and buff building brick works outside of Allegheny county.
Table IV. List of red brick works in Allegheny county.
Table V. Statistical summary of the pottery industry.
Table VI. Statistical summary of the fire-clay industry.
Table VII. Statistical summary of the building brick industry.
Table VIII. Statistical summary of clay industries in Western Pennsylvania.
Table IX. Statistical summary of clay industries in Pennsylvania for 1896.
Table X. Statistical summary of clay industries in United States in 1896.
Table XI. Analyses of fire-clays mined in Western Pennsylvania.
Table XII. Analyses of fire-clays and pottery clays from different localities.
Table XIII. Analyses of pot clays, kaolins and slip clays.

TABLE 1.

List of potteries and allied industries in Western Pennsylvania, giving name and address, kinds of clay used, kind of ware manufactured and date when started.

Locality.	Name.	Date when started.	No. of kilns.	Kind of Clay.	Kind of Products.
1. New Geneva,	C. L. Williams & Co.,	1854 1897	2	Clay from river terrace,	Blue stoneware.
2. Greensboro,	Hamilton & Jones,	1857 1897	3	Clay from river terrace,	Blue stoneware.
3. Point Marion,	Union Pottery Co.,	1897	1	Clay from river terrace,	Blue stoneware.
4. Kittanning,	Wick China Co.,	1890	8	Clay, feldspar and flint imported,	China ware.
5. Pittsburgh,	Star Encaustic Tile Co.,	1876 1887	2	Pittsburgh and New Brighton clays,	Floor tiling.
6. Pittsburgh,	Erb Pottery,			Pittsburgh clay,	Red flower pots.
7. Pittsburgh,	Pittsburgh Clay Pot Co.,			See fire clays.	
8. Pittsburgh,	Phoenix Clay Pot Co.,				
9. New Brighton,	Pittsburgh Clay Mfg. Co., New Brighton pottery,	1862	9	Native and imported clays,	Stoneware.
10. New Brighton,	Pittsburgh Clay Mfg. Co., Sewer Pipe Works,	1887	14	New Brighton clay,	Sewer pipe.
11. New Brighton,	Pittsburgh Clay Mfg. Co., Flue Lining Works,	1887	10	New Brighton clay,	Flue linings.
12. New Brighton,	Pittsburgh Clay Mfg. Co., Oak Hill pottery,	1893	2	New Brighton and terrace clay,	Red flower pots.
13. New Brighton,	Sherwood Bros.,	1878	4	New Brighton clay,	Stoneware.
14. New Brighton,	Enterprise Pottery Co.,	1881	3	New Brighton clay,	Stoneware.
15. New Brighton,	American Porcelain Co.,	1894	4	New Brighton clay,	Porcelain lined ware.
16. New Brighton,	The Beaver Valley Pottery,	1891		Now idle,	Yellow ware.
17. Fallston,	The Fallston Pottery Co.,			Now idle,	Stoneware.
18. Rochester,	Keystone Pottery Co.,	1890-95		Now idle,	Stoneware.
19. Beaver Falls,	The Mayer Pottery Co. (Limited),	1880	5	Imported and New Brighton clays,	Ironstone china ware.
20. Beaver Falls,	The Beaver Falls Art Tile Co.,	1887	5	New Brighton and imported clays,	Decorative tile.

TABLE II.

Showing the name and address of fire brick manufacturers in Western Pennsylvania, capacity of works, kind of material used, kind of ware manufactured, and date when started.

Location.	Name of Company.	When started.	Capacity per day.	No. of kilns.	Kind of Materials Used.	Products.
ALLEGHENY VALLEY.						
1. Manorville,	Phoenix Fire Brick Works,	1864 1896	28,000	6	Sandstone and lime,	Silica brick.
2. Cowanshannoc,	Phoenix Fire Brick Works,	1879		6	Flint and plastic fire clay,	Fire brick.
KISKIMINITAS AND CONEMAUGH VALLEYS.						
3. Salina,	Kier Brothers,	1845	14,000	7	Flint and plastic clay,	Fire brick.
4. Black Lick,	The Burl Fire Brick Co.,	1867 1896	20,000	4	Flint, plastic clay and ganister,	Fire, building, paving and silica brick.
5. Bolivar,	Reese, Hammond & Co.,	1857	65,000	20	Flint, plastic clay and ganister,	Fire, building, paving and silica brick.
6. Bolivar,	Garfield Fire Clay Co.,	1889	20,000	4	Flint and plastic clay,	Fire brick, sp. locomotive tiling.
7. Bolivar,	Lincoln Fire Brick and Shape Co.,	1872	....	4	Flint and plastic clay,	Not in operation.
8. Lockport,	Jas. Gardner, Jr.,	1863	10,000	3	Flint and plastic clay,	Gas retorts, etc.
9. Johnstown,	A. J. Haws & Son,	1859	57,000	17	Flint, plastic clay and ganister,	Fire brick and silica brick.
10. Johnstown,	M. L. Williams & Co.,	1889	....	4	....	
11. Johnstown,	Hiram Swank & Sons,	1856	*	6	Flint, plastic clay and ganister,	Fire brick.
12. Kingston,	The Wm. Stuart Silica Brick Co.,	1896	5,000	3	Ganister and lime,	Silica brick.
13. Hunker Station,	The Westmoreland Fire Brick Co.,	1891	20,000	†1	Hard and soft fire clay,	Not in operation in 1897.
YOUGHIOGHENY RIVER VALLEY.						
14. Layton Station,	Layton Fire Clay Co.,	1890	30,006	6	Hard and soft fire clay,	Fire, paving and building brick.
15. Layton Station,	Stuart Fire Brick Co.,	1893	8,000	4	Ganister, lime, soft clay and blue clay,	Silica and sand brick.
16. Layton Station,	Silica Brick Co.,	1896	....	3	....	Not in operation.
17. Lavenia Station,	Crescent Fire Brick Co.,	....	....	5	....	Not in operation.
18. Connellsville,	Joseph Soisson Fire Brick Co.,	1864 1871 1878	20,000 11,000 10,000	5 5 5	Flint and plastic clay and shale,	Fire, building and paving brick, three yards.
19. Dunbar,	Dunbar Fire Brick Co.,	....	20,000	5	Hard and soft fire clay,	Fire, building and paving bricks.
20. Mt. Braddock,	Eureka Fire Brick Works,	1883	12,000	7	Fire clay,	Fire brick and paving brick.
21. Lemont,	McClure Coke Co.,	1872	9,000	4	Fire clay,	Fire brick.

MONONGAHELA VALLEY.						
22. Courtney,	John Tempest & Co.,	1890	5,000	8	Fire clay,	Pipe shapes.
23. Manown,	Tempest Fire Brick Co.,	1892	10,000	14	Fire clay,	Pipe shapes, fire bricks.
24. Manown,	The Manown Manufacturing Co.,	1896	15,000	8	Fire clay,	Pipe shapes, fire bricks.
OHIO VALLEY.						
25. Monaca,	Welch, Gloninger & Co.,	1881	20,000	†1	Fire clay,	Fire brick.
26. Beaver,	The Stahl Fire Brick Co.,	1848 1887	8,000	4	Fire clay,	Fire brick.
27. Vanport,	Welch, Gloninger & Co.,	1886	12,000	3	Fire clay,	Fire brick and building brick.
28. Mahan,	Park Fire Clay Co.,					Not in operation in 1897.
29. Rochester,	S. Barnes & Co.,	1889	20,000	7	Fire clay,	Fire brick and stove linings.
30. New Brighton,	Ingram & Co.,	1880	8,000	3	Fire clay,	Fire brick.
31. New Brighton,	A. F. Smith & Son,	1845 1897	30,000	6	Fire clay,	Fire brick, fire-clay and potter's clay.
32. Pittsburgh,	Harbison & Walker,	1865	60,000	†72	Fire clay,	Fire brick.
33. Pittsburgh,	Iron City Fire Brick Co.,		3,000	9	Fire clay,	Fire brick; recently removed to Sandy Ridge.
34. Pittsburgh,	Pittsburgh Clay Pot Co.,				Fire clay,	Glass pots.
35. Pittsburgh,	Phoenix Clay Pot Works,			2	Fire clay,	Glass pots, tank and furnace blocks.
THE FOLLOWING MINE AND SHIP FIRE CLAY BUT HAVE NO WORKS.						
36. G. Dando & Brother,	Freedom,				Ground fire clay.	
37. David Coulter,	Bolivar,				Fire clay for gas retorts.	
38. D. H. Emme,	White House,				Glass pot clay.	
39. Kennedy & McFarlane,	Ohio Pyle,				Flint fire clay.	
40. Mr. Paul,	Stewarton,				Flint fire clay.	
41. Mrs. M. J. Wurm,	Layton Station,				Glass pot clay.	
42. D. B. Wilson,	Mineral Point,				Flint fire clay.	
43. D. Page,	South Fork,				Flint fire clay.	

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*Two car loads.

†A continuous chambered kiln.

TABLE III.

List of manufacturers of red and buff building brick in Western Pennsylvania, showing capacity of the works, number of kilns, kinds of clay, kinds of brick produced and date when started.

Locality.	Name of Company.	Date.	Capacity per day.	No. of kilns.	Kinds of Clay.	Kinds of Brick.
BUFF AND ORNAMENTAL BRICK.						
1. Fallston,	Fallston Fire Clay Co.,	1891	20,000	12	Plastic fire clays,	Buff and colored building, paving and fire brick.
2. Monaca,	Welch, Gloninger & Co.,	1881	20,000	1	See fire brick.	
3. Vanport,	Vanport Brick Co.,	1867 1897	20,000	5	Plastic fire clay,	Buff and colored building, paving and fire brick.
4. Kittanning,	Kittanning Clay Manufacturing Co.,	1896	30,000	6	Plastic fire clay and shale,	Building brick, paving brick and drain tile.
5. Kittanning,	Kittanning Brick and Fire Clay Co.,	1894	30,000	10	Plastic fire clay,	Buff and colored building brick.
6. Bolivar,	Reese, Hammond & Co.,	....	....	....	See fire brick.	
7. Layton Station,	Layton Fire Clay Co.,	....	....	....	See fire brick.	
8. Fairchance,	Fairchance Lumber and Brick Co.,	1882	15,000	4	Clay and shale,	Red and buff building and paving brick.
RED BRICK.						
9. Freeport,	John Coward,	....	....	3	Alluvium,	Not in operation.
10. Ford City,	The Manor Brick Co.,	1888	15,000	3	Clay and shale,	Red building brick.
11. Hyde Park,	Kuhn & Schaeffer,	1892	15,000	2	Alluvium and shale,	Red building and paving brick.
12. Blairsville,	J. D. Neff Brick Co.,	1890 1897	10,000	4	Shale and clay,	Red building brick.
13. Blairsville Intersection,	Branch Brick Co.,	....	20,000	2	Shale,	Red building brick.
14. Sheridan,	Louis Whein,	....	1,000	2	Surface clay,	Red building brick.
15. Johnstown,	Cambria Iron Co.,	1884	30,000	3	Clay,	Red building brick.
16. Irwin,	J. M. Rumbaugh Brick Co.,	1896	30,000	4	Shale,	Red building and ornamental brick.
17. Calumet,	J. M. Rumbaugh Brick Co.,	1888	70,000	4	Shale,	Red building and ornamental brick.
18. Pitcairn (Wall),	....	....	....	....	See Allegheny county,	Red building and ornamental brick.
18. Jeannette,	Standard Brick Co.,	1889	18,000	2	Shale,	Red building brick.
20. Greensburg,	W. W. Parks,	1889	7,000	2	Shale,	Red building and pressed brick.
21. Ligonier,	John Robb,	1877	3,000	2	Alluvium,	Red building brick, hand made.
22. Mt. Pleasant,	Chas. Hays,	....	....	3	Alluvium,	Red building brick.
23. West Newton,	John F. Cruthers,	1879	10,000	2	Alluvium,	Red building brick.
24. West Newton,	T. A. Humphrey,	1890	20,000	2	Shale,	Red building brick.
25. Dawson,	P. G. Smith,	....	....	1	Alluvium,	Red building brick.
26. Connellsville,	Soisson & Schlosser,	1896	8,000	2	Clays,	Red building brick.
27. Connellsville,	Bird & Fancher,	1897	4,000	1	Terrace clay,	Red building brick, hand made.

28. Uniontown,	J. V. Williams & Co.,	1847 1897	40,000	3	Surface clay,	Red building brick.
29. Uniontown,	W. L. Robinson,	1898	10,000	3	Surface clay,	Red building brick.
30. Fairchance,	Fairchance Lumber and Brick Co.,	....	....	....	See buff brick.	
31. Fairchance,	Fairchance Brick and Tile Co.,	1897	15,000	2	Surface clay,	Red building brick.
32. Smithfield,	A. J. Hayden,	1897	3,000	1	Surface clay,	Red building brick, hand made.
33. Monongahela City,	J. T. Conlin,	1884	5,000	5	Alluvium,	Red building brick.
34. Charleroi,	The Charleroi Brick Co.,	1892	20,000	3	Red and yellow clay,	Red building brick.
35. Fayette City,	Dinsmore Bros.,	1892	10,000	2	Shale and fire clay,	Red building and fire brick.
36. California,	F. H. Martin,	1872	40,000	2	Alluvium,	Red building brick.
37. New Brighton,	A. Dewhirst & Bro.,	1874	10,000	2	Terrace clay,	Red building brick.
38. Rochester,	Park Fire Clay Co.*					
	Freedom, two yards,	......	90,000	47	Lower Kittanning fire clay,	Paving and building brick.
	Monaca,	......	25,000	10		
	Fallston,	......	20,000	12		

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*The Park Fire Clay Co. would give no information. The figures are estimates by the writer, except the kilns, which were counted.

TABLE

The Brick Yards of

No.	Name of company.	Office address.	Location of yard.
	a. PITTSBURGH BRICK YARDS.		
1	R. Knowlson & Son,	At yard,	925 Vickroy street,
2	Boyd Hill Brick Co.,	At yard,	Vickroy and Magee streets,
3	Booth & Flinn,	1942 Forbes street,	Ruch's Hill,
3a.	Pittsburgh Terra Cotta Lumber Co.,	At yard,	Bedford avenue,
4	Albert Neely,	At yard,	Tustin and Jumonville streets,
5	American Clay Manufacturing Co.,	At yard,	Frazier and Griffith streets,
6	Mrs. A. M. Entress,	At yard,	Webster and Lawson streets,
7	Harbison & Walker,	At yard,	Twenty-second st. & A. V. R. R.,
8	W. and J. Francies,	At yard,	Liberty avenue and 34th street,
9	Evan Jones,	Carnegie building,	Liberty avenue and 36th street,
10	Hooper Bros.,	At yard,	Bellefield and Centre avenues,
11	Blair Bros.,	At yard,	Edmond street near Liberty ave.,
12	Sankey Bros.,	2101 Carson st., S. S.,	Atlantic avenue, E. E.,
13	Iron City Brick and Stone Co.,	At yard,	Stanton ave. & McCandless st.,
14	Thos. Marshall,	5020 Cypress st., E.E.,	Kelly street, E. E.,
15	Jno. W. Beckett,	At yard,	Hamilton & Dallas aves., E. E.,
	b. SOUTH SIDE BRICK YARDS.		
16	West End Brick and Stone Co.,	121 Wabash avenue,	Thirty-fifth ward,
17	Minsinger Bros.,	At yard,	Prospect street, 32d ward,
18	Knoxville Land Improvement Co.,	86 Knox avenue,	Knoxville borough,
19	Sankey Bros.,	2101 Carson street,	S. Eighteenth street,
20	J. & H. Benz,	At yard,	S. 18th st. and Quarry Road,
21	Keeling Brick Co.,	2014 Josephine street,	Quarry Road,
22	M. Lanz & Sons,	S. 29th & Carson sts.,	S. Thirty-fourth street,
23	S. S. Brick and Stone Co., Ltd.,	At yard,	S. Thirty-third street,
	c. ALLEGHENY BRICK YARDS.		
24	Geyer Bros.,	At yard,	Woodland avenue,
25	Miller Bros.,	At yard,	Charles street,
26	Huckestein Brick and Stone Co.,	37 Fairmount st.,	Nunnery Hill,
	d. ALLEGHENY VALLEY BRICK YARDS.		
27	Battenfield & Schulze,	73 Grant avenue,	Millvale borough,
28	Guyasuta Brick Co., Ltd., No. 1,	18th st. & W.P.R.R.,	Sharpsburg,
29	Guyasuta Brick Co., Ltd., No. 2,	18th st. & W.P.R.R.,	Sharpsburg,
35	Kountz Bros. Co.,	At yard,	Harmarville,
36	Blatchford, Meeds Brick Co.,	At yard,	Barking Station,
37	McFetridge Bros.,	At yard,	Hite Station,
38	Wittmer Brick Co.,	12 Federal street, Allegheny,	Wittmer Station,
	e. OHIO VALLEY BRICK YARDS.		
39	Ft. Pitt Stone and Brick Co.,	Carnegie,	Ft. Pitt,
40	Carnegie Brick Co.,	At yard,	Carnegie,
41	Penn Brick Co., Limited,	At yard,	Leetsdale,
42	Harmony Brick Co.,	At yard,	Leetsdale,
43	Pittsburgh Brick Co.,	644 Grant st., Pittsburgh,	Briggston,
	f. MONONGAHELA VALLEY BRICK YARDS.		
44	J. K. & S. D. Mills,	818 Main st., Braddock,	Copeland Station,
45	Keller & Milliken,	Eighth street,	Braddock,
46	J. R. Ward & Sons,	817 Penn avenue, Wilkinsburg,	Brinton,
47	J. M. Rumbaugh Brick Co.,	Greensburg, Wilkinsburg,	Pitcairn,
48	Keystone Brick Co., Limited,	At yard,	McKeesport,
49	Tube City Brick Co.,	At yard,	McKeesport,
50	Standard Brick Co.,	701 Fifth avenue,	McKeesport,
51	Glassport Brick Co.,	515 Walnut st., McKeesport,	Glassport,
52	Monongahela Brick Works,	At yard,	Blair Station,
53	A. M. Pierce,	W. Elizabeth,	W. Elizabeth,
	YOUGHIOGHENY VALLEY BRICK YARDS.		
54	Christy Park Brick Works,	At yard,	Christy Park borough,
55	C. M. C. Harper & Co.,	At yard,	Boston,
56	Yough Brick Co.,	326 Fourth avenue, Pittsburgh,	Greenock Station,
57	Greenock Brick Works,	At yard,	Greenock Station,

IV.

Allegheny County.

When started.	Months operated in 1897.	Men and boys.	Kilns.	Capacity per day.	Material used.	Products.
1845	5	27	4	15,000	Clay and shale,	Common red brick.
1885	....	35	4	20,000	Clay and shale,	Common red brick.
1889	12	120	10	125,000	Clay and shale,	Common red and stock brick.
....	....	60	....	*35,000	Clay and shale,	Terra cotta lumber.
1875	....	5	3	5,400	Clay, ...	Common red brick.
1896	12	20	3	20,000	Clay and shale,	Common, vitrified, pressed brick.
1882	10	25	3	20,000	Clay and shale,	Common red and stock.
....	....	....	....	....	....	Fire brick.
1894	10	36	4	20,000	Clay and shale,	Common red and stock brick.
....	....	....	....	....	Clay and shale,	Common red brick.
1890	....	14	3	15,000	Clay and shale,	Common red and stock brick.
1885	11	22	5	16,000	Clay, ...	Common red and stock brick.
1880	11	25	4	15,000	Clay, ...	Common red and stock brick.
1891	....	18	4	15,000	Clay and shale,	Common red brick.
1894	6	11	3	6,700	Clay, ...	Common red brick.
1877	9	30	4	15,000	Clay, ...	Common red and stock brick.
1894	....	23	3	16,000	Clay and shale,	Common red brick.
1886	3	17	3	10,000	Clay and shale,	Common red brick.
1881	9	20	4	10,000	Clay and shale,	Common red and stock brick.
1866	12	35	6	20,000	Clay and shale,	Common, stock, pressed brick.
1882	....	25	4	15,000	Clay and shale,	Common red brick.
1887	8	25	5	15,000	Clay and shale,	Common red brick.
1887	11	20	5	20,000	Clay and shale,	Common, stock, buff & pressed brick.
1890	9	32	5	17,000	Clay and shale,	Common red and stock brick.
1882	....	16	3	7,000	Clay, ...	Common red brick.
1891	10	30	4	25,000	Clay and shale,	Common red brick.
1882	Idle.	....	3	13,000	Clay and shale,	Common red brick.
1896	....	15	3	18,000	Clay and shale,	Common red brick.
1896	....	30	3	20,000	Clay, ...	Common red brick.
1896	....	25	3	20,000	Clay, ...	Common red brick.
1892	4	40	7	35,000	Clay and shale,	Paving, pressed and common brick.
1893	....	26	6	16,000	Clay and shale,	Com., repressed, paving & stock br.
1884	12	24	4	18,000	Clay and shale,	Common red brick.
1884	....	50	4	50,000	Clay and shale,	Common red brick.
1897	4	15	1	25,000	Clay and shale,	Common red brick.
1892	5	13	3	10,000	Clay, ...	Common red brick.
1892	9	34	5	20,000	Clay, ...	Common red and stock brick.
1887	8	27	7	20,000	Clay, ...	Common red brick.
1894	....	22	4	30,000	Clay and shale,	Common red and pressed brick.
1897	2	10	2	....	Clay and shale,	Common red brick.
1891	....	24	3	15,000	Clay, ...	Common red and stock brick.
1896	....	10	3	10,000	Clay and shale,	Common red brick.
1892	....	40	5	60,000	Clay and shale,	Common red and pressed brick.
1892	....	24	3	15,000	Clay and shale,	Common red and stock brick.
1892	....	18	3	15,000	Clay and shale,	Common red and repressed brick.
1893	5	14	2	10,000	Clay and shale,	Common red and dry repressed brick.
....	....	23	3	15,000	Clay and shale,	Common red brick.
....	Idle.	....	5	50,000	Clay.	
....	Idle.	....	4	....	Clay.	
1887	1	11	2	12,000	Clay, ...	Common red brick.
1885	....	23	3	15,000	Clay and shale,	Common red and stock brick.
....	4	12	4	18,000	Clay and shale,	Common, dry pressed, stock & buff br.
1886	....	16	4	18,000	Clay, ...	Common red brick.

*Tons per year.

TABLE V.

Statistical summary of the fire-clay industry in western Pennsylvania.

Capital invested in the pottery business,	$1,010,840
Value of the output for 1897,	713,251
Value of the output for 1896,	642,240
Number of men employed in 1897,	928
Number of companies in 1897,	14
Number of kilns in 1897,	71

The above includes the output from all the stoneware potteries (6), the earthenware (2), the china and whiteware (2), encaustic and enameled tile works (2), one hollowware company, one sewer-pipe works and one flue-lining factory.

TABLE VI.

Statistical summary of the pottery industry in western Pennsylvania:

1. Capital invested in 1897,	$3,179,817
17 companies reported,	2,504,863
Estimate for 9 companies who did not report,	674,954
2. Value of the output for 1897,	1,485,748
17 companies reported,	1,285,748
Estimate for the 9 companies failing to report,	200,000
3. Value of output for 1896,	1,591,916
17 companies reported,	1,351,916
Estimate for 9 other companies,	210,000
4. Number of men employed in 1897,	1,624
5. Capacity of works per day in fire brick,	497,000
6. Number of companies or individuals who mine clay, but do not manufacture,	10
Number of kilns,	271
7. Estimated value of fire-clay mined and sold, not included in No. 2,	$40,000
8. Estimated value of the glass pots and gas retorts produced in 1897,	300,000
9. Value of the output of all the fire-clay products in the river valley regions of western Pennsylvania for 1897,	1,825,748
10. Value of the fire brick produced in Pennsylvania for 1896,	2,083,414
11. Value of the fire brick produced in U. S. for 1896,	4,906,923

TABLE VII.

Statistical summary of the building brick industry in the river valley regions of western Pennsylvania:

Capital invested,	$2,644,954
Buff and ornamental brick,	183,000
Red brick outside of Allegheny county,	249,650
Red brick in Allegheny county,	2,212,304
Value of the output for 1897,	1,411,130

Buff and ornamental brick,	155,500
Red brick outside of Allegheny county,	213,755
Red brick in Allegheny county,	1,041,875
Value of the output for 1896:	
Buff and ornamental brick,	111,000
Red brick outside of Allegheny county,	151,713
Red brick in Allegheny county,	
Number of men employed in 1897,	1,733
Buff and ornamental brick,	134
Red brick outside of Allegheny county,	384
Red brick in Allegheny county,	1,215
Number of kilns in use,	304
Daily capacity,	1,615,000
Outside of Allegheny county,	549,200
In Allegheny county,	1,066,000
Number of brick companies operating works in 1897,	89
Outside of Allegheny county,	37
In Allegheny county,	52

TABLE VIII.

Statistical summary of the clay industries in the river valleys of western Pennsylvania.

Item.	Potteries.	Fire brick.	Building brick.	Total.
Capital invested in 1897,	$1,010,840	$3,179,817	$2,644,954	$6,835,611
Value of the output for 1897,	713,251	1,485,748	1,411,130	3,610,129
Daily capacity in bricks,	....	497,000	1,615,000	2,112,000
Number of companies,	14	36	89	139
Number of kilns,	71	271	373	715
Number of men employed,	928	1,624	1,851	4,403

The above figures do not include the output or capital of the Park Fire Clay Co., nor of one of the glass-pot companies, nor the glass pots manufactured by the glass companies, nor the gas retort works at Lockport, all of which would probably bring the total invested capital to seven million dollars or more, and the value of the output to nearly four million dollars. It may be interesting to compare the following statistics for the whole state, which are copied from the mineral resources of the United States, published by the United State Geological Survey.

TABLE IX.

Statistical summary of the clay industries in Pennsylvania for the year 1896.*

Value of all the clay products in Pennsylvania produced in 1896,	$9,063,313

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*Compiled from the Min. Resources in the 18th An. Rept. U. S. Geol. Surv. The returns for 1897 are not yet available.

Value of the common brick produced in 1896,	4,118,206
Value of the fire brick,	2,083,414
Value of the pressed brick produced in 1896,	662,188
Value of the paving brick produced in 1896,	404,182
Value of the fancy brick produced in 1896,	30,545
Value of the drain tile produced in 1896,	49,039
Value of the pottery produced in 1896,	617,601

TABLE X.

Value of the clay products of the United States in 1896.*

State.	Fire brick.	Total brick and tile.	Total pottery.	Grand total.
Alabama,	$900	$365,760	$6,425	$372,185
Arizona,	....	55,663	....	55,663
Arkansas,	2,000	193,832	22,600	216,332
California,	10,836	663,185	17,022	680,207
Colorado,	42,264	328,680	....	328,680
Connecticut,	64,000	1,102,898	48,700	1,151,598
Delaware,	....	61,003	....	61,003
District of Columbia,	....	350,565	3,000	353,565
Florida,	....	119,844	2,300	122,144
Georgia,	29,950	897,653	7,160	904,813
Idaho,	....	16,000	....	16,000
Illinois,	117,040	5,441,765	421,482	5,863,247
Indiana,	12,510	2,545,980	128,345	2,674,325
Iowa,	5,920	1,901,623	43,035	1,944,658
Kansas,	27,000	252,837	7,250	260,087
Kentucky,	126,539	735,059	95,750	830,809
Louisiana,	50	401,812	600	402,412
Maine,	37,501	956,681	250	956,931
Maryland,	232,270	1,422,359	27,696	1,450,055
Massachusetts,	187,710	2,056,631	206,343	2,262,974
Michigan,	3,575	985,255	20,150	1,005,405
Minnesota,	2,000	555,265	41,436	596,701
Mississippi,	3,300	223,809	1,000	224,809
Missouri,	484,415	2,629,312	50,933	2,680,245
Montana,	69,035	276,311	....	276,311
Nebraska,	....	144,373	....	144,373
New Hampshire,	12,400	581,169	17,000	598,169
New Jersey,	456,825	3,658,861	1,069,142	4,728,003
New York,	302,407	6,102,473	311,733	6,414,206
North Carolina,	6,140	408,544	14,955	423,499
North Dakota,	....	59,625	....	59,625
Ohio,	696,175	7,050,221	2,899,350	9,949,571
Oklahoma,†	....	38,444	....	38,444
Oregon,	15,248	118,545	7,800	126,345
Pennsylvania,	2,250,790	8,445,712	617,601	9,063,313
Rhode Island,	3,000	297,000	....	297,000
South Carolina,	19,750	353,175	1,100	354,275
South Dakota,	....	53,004	....	53,004
Tennessee,	24,956	499,664	37,661	537,325
Texas,	7,060	857,672	58,081	915,753
Utah,	5,750	137,573	....	137,573
Vermont,	....	83,274	....	83,274
Virginia,	1,750	869,086	10,440	879,526
Washington,	12,500	160,348	1,180	161,528
West Virginia,	4,000	492,237	410,707	902,944
Wisconsin,	1,200	760,785	12,500	773,285
Wyoming,	....	9,659	....	9,659
United States,	$5,279,004	$55,721,226	$6,620,627	$62,341,853
Per cent. of total,	8.08	89.38	10.62	100.00

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*From the Eighteenth Annual Report U. S. Geol. Survey, Pt. V (cont'd), p. 1077.

†Including Indian Territory and New Mexico.

TABLE XI.

Analyses of fire-clays mined in western Pennsylvania.

Locality.	Silica. SiO_2.	Alumina. Al_2O_3.	Iron oxide. FeO.	Titanic oxide. TiO_2.	Lime. CaO.	Magnesia. MgO.	Alkalies. Na_2O. K_2O.	Water. H_2O.	Authority.
1. Bolivar, E. Robinson, flint clay, ...	50.840	30.745	3.213	1.260	.160	.288	.541	13.050	2d. Pa. Geol. Surv., H4, p. 32.
2. Bolivar, E. Robinson, plastic clay, ...	59.830	24.580	1.655	1.170	.280	.872	3.114	7.830	2d. Pa. Geol. Surv., H4, p. 32.
3. Bolivar, Reese, Ham. & Co., flint clay,	63.81	26.39	(4)1.23	....	tr.	tr.	....	(3)9.12	State College chem. laboratory.
4. Black Lick, E. J. Meldren, flint clay, ..	64.830	23.950	.900	.880	.110	.187	.296	9.390	2d Pa. Geol. Surv., H4, p. 32.
5. Black Lick, E. J. Meldren, plastic clay,	63.490	18.460	1.566	2.150	.230	.551	2.755	6.310	2d Pa. Geol. Surv., H4, p. 32.
6. Salina, Kier Bros., flint clay, top layer,	47.250	34.350	.693	1.990	.580	.090	.261	13.695	2d Pa. Geol. Surv., M. M., p. 259.
9. Salina, Kier Bros., plastic clay, ...	55.330	27.841	2.916	1.140	.580	.756	3.916	7.495	2d Pa. Geol. Surv., M. M., p. 259.
10. Laughlinstown, Robt. Hall, flint clay, ..	55.680	29.180	.837	1.490	.130	.180	.245	12.490	2d Pa. Geol. Surv., M. M., p. 260.
11. Jacob's Creek, "furnace clay," plas. clay,	56.780	26.890	.322	....	.369	.987	3.920	8.380	2d Pa. Geol. Surv., M. M., p. 260.
12. Jacob's Creek, "forge clay," flint clay,	65.370	24.870	.756	....	.168	.234	.010	8.790	2d Pa. Geol. Surv., M. M., p. 260.
13. Ohiopyle, Geo. Potter, flint clay, ...	52.230	31.310	1.008	1.680	.130	.165	.720	13.190	2d Pa. Geol. Surv., M. M., p. 260.
14. South Fork, flint clay, ...	43.460	41.610	(4)1.030	....	.240	.090	....	(3)13.290	Pa. State College chem. lab.
15. Kittanning, Kittanning clay, ...	60.400	26.230	.230	(5)	.140	.540	2.940	(3)8.710	Pa. State College chem. lab.
16. Layton, glass-pot clay, ...	64.890	24.080	.210	(6)	.410	.190	1.03	(3)9.290	Pa. State College chem. lab.
17. White House, glass-pot clay, ...	54.230	32.800	.21	....	....	....	....	(3)11.940	Pa. State College chem. lab.
18. New Brighton, El. & Sher., No. 1 grade,	61.970	22.940	1.818	1.975	.440	.522	1.750	8.850	2d Pa. Geol. Surv., M. M., p. 262.
19. New Brighton, El. & Sher., No. 2 grade,	61.750	23.660	1.930	1.780	.455	.353	2.418	7.880	2d Pa. Geol. Surv., M. M., p. 262.
21. New Brighton, El. & Sher., raw, ...	62.260	23.890	1.408	1.780	.470	.309	1.977	7.640	2d Pa. Geol. Surv., M. M., p. 262.
22. New Brighton, Sherwood Bros., ...	63.55	24.88	1.17	....	.56	.470	2.27	6.96	Ohio Geol. Surv., Vol. VII, p. 94, Orton.
23. New Brighton, Mend. & Chamb., ...	66.610	18.390	1.964	2.810	.490	.547	1.079	7.495	2d Pa. Geol. Surv., M. M., p. 262.
25. New Brighton, Couch's clay, ...	57.670	27.520	1.494	2.540	.380	.122	.619	9.680	2d Pa. Geol. Surv., M. M., p. 262.
26. New Brighton, Fish estate, ...	66.700	22.870	.280	(7)	.230	.520	2.92	5.83	Pa. State College Chem. Lab.
27. Rochester, S. Barnes & Co., ...	61.980	23.880	1.395	1.830	.040	.281	1.217	9.280	2d Pa. Geol. Surv., M. M., p. 262.
28. Vanport, Severn's clay, ...	60.190	24.230	2.097	2.345	.850	.036	1.669	9.015	2d Pa. Geol. Surv., M. M., p. 262.
31. Layton, J. S. Wilgus, ...	57.430	26.050	1.629	1.330	.580	.980	4.537	7.890	2d Pa. Geol. Surv., M. M., p. 267.
32. Connellsville, J. Soisson & Co., ...	56.885	28.250	.810	1.500	.290	.136	.538	12.290	2d Pa. Geol. Surv., M. M., p. 267.
33. Moyer, J. Soisson & Co., ...	55.280	34.170	2.210	....	1.370	2.110	....	....	
34. Bailey Point, J. Soisson & Co., ...	60.800	28.100	.450	....	.240	.090	.300	9.600	J. H. Cremer.
36. Brady's Run, B. R. Fire Brick Co., ...	68.92	22.38	.980	....	.19	.172	....	6.14	Min. Res. U. S., 1896, p. 55.
37. Manown, Pa., ...	64.17	29.75	2.600	....	.40	.12	....	....	Manown Manufacturing Co.
38. Hunker Station, Pa., ...	41.75	40.09	.65	....	.03	1.02	....	13.20	Westmoreland Fire Brick Co.
39. Queen's Run, Pa., ...	50.80	32.28	1.77	....	.05	.47	4.56	8.94	Queen's Run Fire Brick Co.

(1) Sand, 34.250; silica in the sand, 34.120.
(2) Sand, 35.51; silica in the sand, 35.1.
(3) Loss on ignition.
(4) Determined as Fe_2O_3.
(5) Fe_2O_3 equals 1.34.
(6) Fe_2O_3 equals 0.29; compare with Nos. 4-12 in the following table.
(7) Fe_2O_3 equals 1.12.

TABLE XII.

Analyses of fire-clays and pottery clays.

No.	Locality.	Silica.	Alumina.	Ferric oxide.	Lime.	Magnesia.	Alkalies.	Water.	Authority.
	FIRE-CLAYS.								
1	Black Rock, Arkansas,	84.24	11.50	.08	.52	.02	.42	3.98	Jour. Chem. Soc., Vol. 17.
2	Golden, Colorado,	49.54	34.04	.88	.61	.36	tr.	13.91	Golden Pressed and Fire Brick Co.
3	Flushing, Michigan,	70.55	21.20	3.20	1.90	1.50	1.65	....	Saginaw Clay Manufacturing Co.
4	Mexico, Missouri,	53.77	30.90	1.74	.39	.32	.49	12.68	Mo. Geol. Surv., Vol. XI, p. 563.
5	Fulton, Missouri,	47.30	37.54	1.48	.57	....	.50	12.76	Mo. Geol. Surv., Vol. XI, p. 563.
6	High Hill, Missouri,	45.12	40.40	.47	.29	tr.	.30	13.34	Mo. Geol. Surv., Vol. XI, p. 566.
7	St. Louis, Missouri,	61.73	23.56	.52	.55	.15	1.00	9.25	Mo. Geol. Surv., Vol. XI, p. 563.
8	Millville, New Jersey,	77.15	15.65	....	tr.	.75	....	5.35	H. Burden.
9	South Amboy, New Jersey,	61.76	26.14	....	.80	....	....	9.60	H. Burden.
10	Woodbridge, New Jersey,	75.74	18.34	....	.06	.66	....	4.58	H. Burden.
11	Massillon, Ohio,	61.58	24.14	1.20	.45	.70	....	11.98	Massillon Stone and Fire Brick Co.
12	Rapid City, South Dakota,	87.05	6.56	.64	.95	1.24	3.01	....	F. C. Smith.
13	Mt. Savage, Maryland,	44.40	38.56	1.08	tr.	.11	.25	14.57	2d Pa. Geol. Surv., M. M., p. 266.
14	Mt. Savage, Maryland,	56.80	30.08	1.12	....	....	.80	10.50	G. H. Cook, Clays of N. J., 1877.
15	New Castle, Ohio,	55.49	28.33	2.46	.26	.08	1.37	11.38	
	POTTERY CLAYS.								
1	Huntingburg, Indiana,	69.23	18.97	0.55	0.12	.36	2.60	5.46	Ind. Geol. Survey, 20th, p. 109.
2	Guthrie, Missouri,	48.92	32.90	3.10	.40	.30	.82	13.58	Mo. Geol. Surv., XI, p. 563.
3	Calhoun, Missouri,	71.94	17.60	2.35	.62	.56	1.50	5.27	Mo. Geol. Surv., XI, p. 564.
4	Field's Creek, Missouri,	55.39	25.79	4.83	.53	.31	3.39	8.60	Mo. Geol. Surv., XI, p. 564.
5	De Soto, Missouri,	49.04	34.85	.71	1.33	1.04	.85	12.33	Mo. Geol. Surv., XI, p. 566.
6	Kreischersville, New York,	64.26	24.76	.83	.73	tr.	2.35	....	
7	Northport, Long Island,	58.84	23.40	1.18	....	....	5.38	9.20	Clay Industries of N. Y., 1895.

TABLE XIII.

Analyses of glass-pot clays, kaolins and slip clays.

No.	Locality.	Silica.	Alumina.	Iron oxide.	Lime.	Magnesia.	Alkalies.	Water.	Authority.
		SiO2.	Al2O3.	Fe2O3.	CaO.	MgO			
	GLASS-POT CLAYS.								
1	Near St. Louis, Mo.,	63.350	22.310	2.700	....	.610	.600	10.430	Pittsburgh Plate Glass Co., No. 6.
2	Ardenne, Belgium,	49.64	34.78	1.80	.680	.410	.410	12.00	Die Feuerfesten Thone, Bischof, 1876.
3	Stourbridge, England,	64.10	22.22	1.92	.14	.18	1.10	7.10	Treatise on Metallurgy, Fuels, 1861.
4	Stourbridge, England,	63.30	23.30	1.80	.73	....	....	10.30	2d Pa. Geol. Surv., M., p. 87.
5	Schwarzenfeld, Germany,	53.10	30.69	3.41	.28	.32	1.33	10.50	Die Feuerfesten Thone, Bischof, 1876.
6	Vallendar, Germany,	46.97	37.95	.95	.04	.11	3.00	10.02	Die Feuerfesten Thone, Bischof, 1876.
7	Bartold, St. Louis Co.,	55.61	27.36	2.73	.87	.07	.71	11.13	Mo. Geol. Surv., Vol. XI, p. 568.
8	St. Louis, Columbia B. road,	52.98	28.87	2.48	.51	.87	1.01	7.73	Mo. Geol. Surv., Vol. XI, p. 570.
9	St. Louis, Jam. French Fire Clay Co.,	52.52	31.40	2.34	.40	.61	.61	12.62	Min. Res. U. S., 1896.
10	Gross Almerode Hesse,	47.50	34.40	1.20	.50	1.00	....	15.4	Am. Mfr. and Iron World, Apr. 22, '98.
	KAOLINS.								
11	Thomas, Pennsylvania,	43.88	40.96	0.82	tr.	tr.	....	13.99	Tenth Census, Vol. 2, p. 1078.
12	Blair county, Pennnsylvania,	70.18	20.99	....	0.65	0.13	....	10.28	Tenth Census, Vol. 2, p. 1078.
13	Near New Castle, Delaware,	72.33	16.75	1.29	2.00	.07	....	7.98	Tenth Census, Vol. 2, p. 1078.
14	Dixon's, New Jersey,	59.93	26.95	1.24	....	.07	.08	10.20	Tenth Census, Vol. 2, p. 1078.
15	Bartow, Lake Co., Flor., washed,	49.30	34.50	.65	....	.14	....	14.78	A. H. Parslow, Tampa, Fla.
16	Lawrence Co., Ind.,	44.75	38.69	.95	.37	.30	.35	15.17	Ind. Geol. Surv., Vol. XX, p. 105.
17	Glen Allen, Missouri,	72.30	18.94	.40	.68	.39	.42	7.04	Mo. Geol. Surv., Vol. XI, p. 563.
18	Chilton, Carter Co., Missouri, washed,	73.82	18.16	1.32	tr.	.21	.24	6.16	
19	Glen Lock, Chester Co., Pa.,	50.96	33.30	....	....	2.42	....	8.95	Min. Res. U. S., 1896.
20	Webster, N. C.,	43.90	40.66	.14	....	....	.46	14.	Min. Res. U. S., 1896.
21	National Kaolin and F. B. Works, Pa.,	71.02	19.72	1.58	.32	.03	.27	7.04	2d Pa. Geol. Surv., An. Rept., 1885, p. 589.
22	National Kaolin and F. B. Works, Pa.,	67.71	20.53	3.12	.39	.04	.29	7.78	2d Pa. Geol. Surv., An. Rept., 1885, p. 589.
23	East Nottingham, Pa.,	46.34	36.32	.64	.04	....	.77	13.75	2d Pa. Geol. Surv., An. Rept., 1885, p. 588.
24	Chestnut Hill, Pa.,	67.01	20.10	3.90	.10	.70	2.00	5.90	2d Pa. Geol. Surv., An. Rept., 1885, p. 588.
	SLIP CLAYS.								
25	Slip clay, Albany, N. Y.,	56.75	15.47	5.73	5.78	3.32	3.25	8.87	Mo. Geol. Surv., Vol. XI, p. 591.
26	Slip clay, Albany, N. Y.,	62.40	10.42	5.36	9.88	4.28	.87	8.05	Mo. Geol. Surv., Vol. XI, p. 591.
27	Slip clay, Albany, N. Y.,	55.60	14.80	5.85	5.70	2.48	4.40	4.94	Geol. Surv. of Ohio, Vol. VII, p. 105; average of several analyses.

LIBRARY OF THE

INDEX.

Page.

Affelder, W. L., 3, 31, 134

Albany slip clay, 28

Allegheny brick works, 152

Allegheny county clay industries, 134, 161

Allegheny valley building brick, 121, 153

Allegheny valley fire brick, 72

Alumina, 64

American Clay Mfg. Co., 144

American Clay Working Co., 6

American Porcelain Co., 40

Analyses of clays, 34, 35, 36, 43, 70, 74, 76, 81, 90, 92, 96, 102, 123, 131, 144, 173, 174, 175, 176

Analyses of fire-clays, 70, 75, 76, 81, 90, 92, 96, 102, 123, 173, 174

Analyses of fire-clays, table, 173, 174

Analyses of glass-pot clays, 176

Analyses of kaolins and slip clays, 176

Bailey Point fire-clay, 94

Ball clay, 23

Barnes, S., & Co., 32, 64, 65

Basic brick, 62

Battenfield & Schulze, 153

Bauxite, 64

Beaver Falls Art Tile Co., 47

Beaver, Pa., fire brick works, 67

Beaver Valley brick works, 118

Beaver Valley Pottery Co., 22, 45

Beckett, Jno. W., 147

Benny & Co., 144

Benz, J. & H., 150

Biscuit wareroom, 24

Black Lick fire-clay, 74, 76

Blair Brothers, 146

Blairsville, 125

Blairsville Intersection, 125

Blatchford Meeds Brick Co., 154

Blue Ball fire-clay, 75, 80

Bonnot, The, Co., 6

Bolivar, 76, 86

Bolivar fire-clay, 73, 76-81, 86, 94

Booth & Flinn, 134, 141

Bowman Brothers, 88

Boyd Hill Brick Co., 140

Brady's Run Fire-Clay Co., 120

Brandywine Summit kaolin, 28

Page.

- Brick, buff, 106
  - burning, 116
  - classification of, 104
  - clays, 101
  - drying, 116
  - fire, 48-100
  - hollow, 108
  - kilns, 116
  - machinery, 108, 111, 112, 113
  - manganese, 107
  - molding, 111
  - ornamental, 105, 106
  - paving,
  - Pompeian, 107
  - red building brick, 100, 162
  - red building brick in Pennsylvania, 118
  - Roman, 104
  - salmon, 104
  - size of, 104
  - stock, 104
  - clays and shales, 101
  - grinding and tempering, 109
  - methods of mining, 109
  - varieties of, 103
- Building brick manufacturers, list of, 166, 168
  - in Allegheny county, 168
  - industry, summary, 170
- California, Pa., 132
- Cambria county fire-clays, 65
- Carbon brick, 64, 71
- Carnegie brick works, 156
- Caruthers, John F., 128
- Chambers Bros. Co., 6
- Charleroi, 131
- Christy Park brick works, 160
- Clarion clay, 31
- Clarion county fire-clays, 65
- Clays, Allegheny county, 137
  - analyses of, 34, 35, 36, 43, 70, 74, 76, 81, 90, 92, 96, 102, 123, 131, 144, 173, 174, 175
  - Beaver Valley, 65, 32
  - Bolivar, 53
  - Clarion, 31
  - composition of, 13
  - definition of, 13
  - fire (see fire-clays).
  - general features of, 13
  - glass pot, 60, 61
  - Lower Freeport, 35
  - Lower Kittanning or New Brighton, 32, 37, 41, 46, 47, 53, 66, 67, 68, 69, 118, 119, 120, 121
  - methods of working, 57
  - Middle and Upper Kittanning, 35, 41
  - origin, 14

Page.
Clays, plastic fire-clay, 53
  potter's, 19, 50
  properties of, 15
  uses of, 16
  value of, 17
  varieties of, 15
  working machinery, 57
Clay Worker, 6
Clearfield county fire-clay, 65
Concentric weathering, 51
Conemaugh Valley building brick, 125
Conemaugh Valley fire brick works, 73
Connellsville, 91, 95, 128
Conlin, J. T., 130
Coulter, David, 19, 86
Courtney fire-clay works, 99
Cowanshannoc fire brick works, 72
Crucibles, 62
Dando, G., & Bro., 66
Davidson fire brick works, 93
Dewhirst, A., & Bro., 120
Dinas brick, 63
Dinsmore Bros., 131, 132
Dry floor, 135
Drying tunnel, 116
Dry pan for grinding clay, 59, 126
Dry press brick, 115
Dunbar Fire Brick Co., 96, 133
Earthenware, 18
Emme, D. H., 97, 98
Enterprise Pottery Co., 40
Entress, Mrs. Annie M., 144
"E. S. & B." pottery, 45
Erb pottery, 18, 31
Eureka fire-brick works, 97, 133
Fallston Fire-Clay Co., 119, 120, 133
Fallston Pottery Co., 31, 46
Fayette City, 131
Fairchance, 129, 133
Feldspar, 14, 28, 46
Filling-in department, China shop, 27
Fire-bricks, 54, 58
  drying, pressing and burning, 59
  shapes, 55
Fire-brick, manufacturers of, 164
Fire-clays, 48, 50, 51, 60, 61, 65
  in Allegheny county, 139
  analyses, 70, 75, 76, 81, 90, 92, 96, 102, 123
  definition, 48
  geologic position of, 53
  industries in western Pennsylvania, 65-170
  plastic, or soft clay, 53
  products, 54

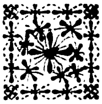
Page.
Fire-clays, tempering and molding, ... 58
varieties of, ... 50
Fish, Levi, & Sons, ... 120
Flint fire-clay, ... 50, 51
Flint fire-clay in Missouri, ... 52
Flue-lining factory, ... 42
Ford City brick works, ... 121
Ford City China factory, ... 29
Fort Pitt Stone and Brick Co., ... 155
Francies, W. & J., ... 145
Freeport, Pa., ... 121
Freese, E. M., & Co., ... 6
Ganister, ... 64, 75
Gardner, Jas., Jr., ... 60, 86
Garfield Fire-Clay Co., ... 84
Gas retorts, ... 60, 86
Geyer Bros., ... 152
Glassport Brick Co., ... 160
Glass pots, ... 60, 61, 71, 72, 90, 98
Glazing stoneware, ... 20, 22
Gloss kilns, ... 23, 29
Glover, James, ... 81
Gob from coal mines, ... 98
Greenock brick works, ... 161
Greensboro brick yard, ... 133
Greensbury, Pa., ... 126, 127
Guyasuta Brick Co., Ltd., ... 153
Hamilton & Jones, ... 25
Hamilton, W. L., ... 25, 36
Hammond, J. B., ... 6
Harbison & Walker, ... 64, 70, 145
Harmony Brick Co., ... 156
Harper, C. M. C., & Co., ... 161
Haws, A. J., & Son, ... 64, 87
Hays, Chas., ... 128
Hice, R. R., ... 6, 120
Hooper Bros., ... 145
Huckestein Brick and Stone Co., ... 152
Humphrey, T. A., ... 129
Hyde Park, Pa., ... 124, 133
Indiana county fire-clays (see Black Lick and Bolivar).
Ingram & Co., ... 66
Iron City Brick and Stone Co., ... 147
Iron City Fire-Brick Co., ... 70, 71
Jeannette, ... 127
Jefferson county fire-clays, ... 65
Jigger department, clay shop, ... 21
J. M. Rumbaugh Brick Co., ... 126
Johnstown building brick, ... 125
Johnstown fire brick, ... 87
Jolly and pull-down, ... 20
Jollying ware, ... 20
Jones, Evan, ... 145

Page.
Kaolin, 13, 24, 28
Keeling Brick Co., 150, 151
Keller & Milliken, 158
Keystone Brick Co., 159
Keystone Pottery Co., 46
Kier Bros., 73, 74
King mines, Bolivar, 77
Kiskiminitas Valley building brick works, 124
Kiskiminitas Valley fire brick works, 73
Kittanning Brick and Fire-Clay Co., 123, 124, 133
Kittanning china factory, 28
Kittanning Clay Manufacturing Co., 18, 121, 122, 123, 133
Knowlson, R., & Son, 140
Knoxville Land and Lumber Co., 149
Kountz Bros. & Co., 153
Lanz, M., & Sons, 151
Latrobe, 127
Lavenia Station, 90
Layton Fire-Clay Co., 88, 133
Layton Station, 61, 88, 89, 90
Lemont Furnace fire brick works, 97
Ligonier brick works, 127
Ligonier pottery, 29
Lincoln Fire Brick and Shape Co., 85
Loud, J. P., 128
MacClure Coke Co. fire brick works, 97
MacFetridge Bros., 154
McNees, Geo., 6
Magnesite brick, 62, 63
Mahan post-office fire brick works, 69
Manganese, 107
Manganese bricks, 107
Manorville fire brick works, 73
Manown Manufacturing Co., 100
Marshall, Thomas, 147
Martin brick machine, 112, 134
Martin, F. H., 132
Martin, The Henry, Brick Manufacturing Co., 6
Mayer Pottery Co., Ltd., 45, 46
Mill brick, 56
Miller Bros., 152
Mills, J. K. & S. D., 157
Minsinger Bros., 149
Monaca fire brick works, 67
Monongahela brick works, 160
    City, 130
    Valley building brick works, 130, 157
        fire brick works, 98
        potteries, 24
Mount Braddock fire brick works, 96
Mount Pleasant, Pa., 128
Moyer fire brick works, 93
Neely, Albert, 144

Page.

New Brighton, Pa., vertical sections at, 30
    building brick, 120
    clays, 31
    potteries, 36
    Pottery Works, 38
New Geneva brick yard, 133
New Geneva pottery, 24
Oak Hill pottery, 43, 44, 45
Ohio Pyle fire-clay, 95
Ohio Valley building brick works, 155
Ohio Valley fire brick works, 65
Park Fire-Clay Co., 69, 133
Parks, W. W., 127
Paving brick industry, 133, 136
Penn Brick Co., Ltd., 156
Phoenix Clay Pot Works, 61, 72
Phoenix Fire Brick Works, 64, 72, 73
Pierce, A. M., 160
Pittsburgh Brick Co., 157
    brick works in, 140
    Clay Pot Co., 61, 71
    Clay Manufacturing Co., 41
    Coal seam, 98, 141
    fire brick works, 69
    Terra Cotta Lumber Co., 108, 137, 142
    tile factory, 29
Plastic fire-clay, 53
Port Marion pottery, 27
Potteries of western Pennsylvania, 24, 163, 170
    list of, 163
    and allied industries, 18
Pressing department, china shop, 29
Printing department, china shop, 26
Pug mill, 110
Reese, Hammond & Co., 51, 64, 74, 77, 82-84, 125, 133
Reese, Isaac, & Sons, 73
Refractory materials, 62
Repressing building bricks, 115
Repressing fire bricks, 84
Robinson, E., 74, 81, 84
Rockingham ware, 22
Rumbaugh, J. M., Brick Co., 126, 127, 128
Rumbaugh Station, 127
Salina, Pa., fire brick works, 73
Sand brick, 63
Sankey Bros., 146, 150
Sewer-pipe press, 42
Sewer-pipe works, 41
Shale, 14, 144
Sherwood Bros. Co., 39
Silica brick, 63
Smith, A. F., 6, 37, 39, 66, 120
Smithfield, 130

Page.
Soisson, Jos., & Co., 91, 133
South Side Brick and Stone Co. (Ltd.), 151
South Side brick works, 148
Standard Brick Co., 127, 159
Stahl Fire Brick Co., 67
Star Encaustic Tile Co., 29
Statistics of clay industries, 161-172
Stewarton fire-clay, 95
Stevenson, J. J., 76, 80
Stoneware, 18
Stoneware clay, 19
Stuart Fire Brick Co., 64
Stuart, The Wm., Silica Brick Co., 64
Swank, Hiram, Sons, 88, 133
Tables of the clay-working industries, 161-172
Tempest, John, & Co., 99
Terrace clay, 25, 35, 43, 139
Terra cotta, 108
Tile, 56
Tile factories, 29, 47
Tube City Brick Co., 159
Turning potters' ware, 19
Uniontown, 129
Vanport Brick Co., 69, 118
Vanport fire brick works, 68, 69
Volcano fire brick works, 91
Ward, J. R., & Sons, 158
Watson Station fire-clay, 100
Welch, Gloninger & Co., 87
West End Brick and Stone Co., 148
West Newton, 128
Wet pan, 57
Wheeler, H. M., 16, 49, 52
White House fire-clay, 97
White ware, 23
Wick China Co., 6, 28
Williams, J. V., & Co., 129
Williams, M. L., & Co., 87
Williams, R. T., 26
Wittmer Brick Co., 155
Wurm, Mrs. M. J., 90
Wymps Gap clay, 61, 98
Yellow, or Rockingham, ware, 22
Youghiogheny Brick Co., 161
    Valley building brick works, 128, 160
        fire brick works, 88



ANNUAL REPORT

OF

The Pennsylvania State College

FOR THE YEAR 1897-98.

Part II.

AGRICULTURAL EXPERIMENT STATION.

Part I contains the Reports of the Departments of Instruction

---

WM. STANLEY RAY,
STATE PRINTER OF PENNSYLVANIA
1898.

☞The bulletins and reports of the Station will be mailed regularly, free of charge, to all residents of the State who request it, so far as the supply will permit. Address, *Director of Experiment Station, State College, Centre County, Pa.*

Visitors will be welcomed at all times and given every opportunity to inspect the Station in all its departments.

THE PENNSYLVANIA STATE COLLEGE

AGRICULTURAL EXPERIMENT STATION.

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Telegraph and Post Office,
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Telephone Connection.

***To June 1, 1898.**
†From June 1, 1898.

OFFICIAL DOCUMENT, No. 21.

TABLE OF CONTENTS.

Page.

Advisory Committee, ... 3

Officers and Assistants, ... 3

Financial statement 1896-7, ... 7

Financial statement 1897-8, ... 9

Report of the Director, ... 11

- Soils and fertilizers, ... 11
- Horticulture, ... 12
- Stock feeding and dairy husbandry, ... 13
- Limitations of station work, ... 13
- The future of the station, ... 14
- Publications, ... 16

The computation of rations for farm animals, by Henry Prentiss Armsby, ... 17

- Introduction, ... 17
- Part I, general principles, ... 18
  - Composition of animals, ... 18
  - Composition of feeding-stuffs, ... 18
  - Digestible matter in feeding-stuffs, ... 19
  - Uses of ingredients of feeding-stuffs, ... 20
  - Nutritive ratio, ... 21
  - Feeding standards, ... 32
- Part II, the computation of rations, ... 24
  - Comparison of a ration with a standard, ... 25
  - Improvement of a ration, ... 26
  - Computation of a ration from given feeding-stuffs, ... 28
  - The selection of feeding-stuffs, ... 30
  - Planning a season's feeding, ... 34
  - The compounding of rations, ... 39
- Part III, the fertilizing value of feeding-stuffs, ... 40
- Appendix of useful tables, ... 42

The comparative value of buckwheat middlings, dried brewers' grains and cerealine for milk and butter production, by Harry Hayward and R. J. Weld, ... 51

- General conclusions, ... 51
- Details of experiment, ... 51
  - The feeding-stuffs, ... 52
  - Plan of Experiment, ... 52
  - Animals, ... 53
  - Sampling, ... 53
  - Rations, ... 54
  - Yield of milk, ... 59
  - Live weight, ... 63
  - Cost and profit, ... 64

The maintenance ration of cattle, by Henry Prentiss Armsby, ... 65

Apples in Pennsylvania, by George C. Butz, ... 72

- Soil, ... 73
- Tilling the soil in young orchards, ... 74
- Cultivation in bearing orchards, ... 74
- Fertilizers, ... 75
- The trees, ... 76

Page.
Pruning at time of planting, 75
Distance to plant, 76
Top grafting, or double working, 77
Choice of varieties, 77
Preservation of apples, 80
Spraying, 81
Insect enemies, 82
Fungous diseases, 84
Small fruits in 1897, by George C. Butz and J. P. Pillsbury, 87
Strawberries, 87
Raspberries, 94
Blackberries, 97
Currants, 99
Gooseberries, 100
The sugar beet in Pennsylvania, by Henry Prentiss Armsby, 101
Nature of the problem, 102
Object of experiments, 102
Plan of experiments, 103
What is a good sugar beet? 103
Results in detail, 104
The season, 115
Future prospects, 117
What to do next, 118
Co-operation by the Experiment Station, 119
Sources of information, 119
Plot experiments with legumes, by W. S. Sweetser, 120
Variety tests of wheat, oats and potatoes, by George C. Watson and Enos H. Hess, 134
Summary, 134
Details of the test, 134
Plots, 135
Condition of soil, 135
Wheat, 135
Oats, 139
Potatoes, 141
General fertilzer experiments, by Enos H. Hess, 146
Plan of the experiments, 146
Results for 1897, 148
Exchanges, 154
Distribution of seeds of varieties of farm crops, 156
List of station publications, 157

SUPPLEMENT.

Investigations on the maintenance ration of cattle, by Henry Prentiss Arsmby, 159

FINANCIAL STATEMENT, 1896-7.

A.—THE UNITED STATES APPROPRIATION FOR THE UNITED STATES FISCAL YEAR ENDING JUNE 30, 1897.

The Pennsylvania State College Agricultural Experiment Station, in account with the United States appropriation, 1897:

Dr.

To receipts from Treasurer of United States, as per appropriation for year ending June 30, 1897, under the act of Congress approved March 2, 1887,			$15,000 00

Cr.

June 30.	By Salaries,	$11,175 89	
	Publications,	1,075 25	
	Postage and stationery,	453 63	
	Heat, light and water,	342 79	
	Chemical supplies,	301 66	
	Seeds, plants, etc.,	45 54	
	Fertilizers,	71 65	
	Feeding stuffs,	861 49	
	Library,	215 95	
	Tools, implements and machinery,	35 07	
	Furniture and fixtures,	71 10	
	Scientific apparatus,	29 96	
	Live stock,	21 53	
	Traveling expenses,	256 40	
	Contingent expenses,	12 73	
	Building and repairs,	29 36	
			$15,000 00

State College, Pa., July 29, 1897.

We, the undersigned, duly appointed auditors of the Experiment Station accounts, do hereby certify that we have examined the books and accounts of the Agricultural Experiment Station of the Pennsylvania State College, for the fiscal year ending June 30, 1897; that we have found the same well kept and classified as above, and that the receipts for the year from the Treasurer of the United States are shown to have been $15,000.00 and the corresponding disbursements

$15,000.00, for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving no balance to be accounted for in the fiscal year commencing July 1, 1897.

(Seal.)

S. R. DOWNING,
H. V. WHITE,
Auditors.

Attest: H. A. McElwain, Custodian.

B.—TOTAL RECEIPTS AND EXPENDITURES, ALL SOURCES, FOR THE YEAR ENDING JUNE 30, 1897.

RECEIPTS.

	United States appropriation account.	General account.	Total.
United States appropriation account,	$15,000 00		$15,000 00
Fertilizer analysis,		$8,535 17	8,535 17
Live stock,		858 57	858 57
Pennsylvania State College,		23 01	23 01
Farm,		894 45	894 45
Excess of expenditures over receipts,		1,515 53	1,515 53
	$15,000 00	$11,826 73	$26,826 73

EXPENDITURES.

Salaries,	$11,175 88	$3,500 06	$14,675 94
Labor,		4,552 93	4,552 93
Publications,	1,075 25	424 20	1,499 45
Postage and stationery,	453 63	331 17	784 80
Heat and light,	342 79	138 96	481 75
Chemical supplies,	301 66	119 68	421 34
Fertilizers,	71 65	15 65	87 30
Feeding stuffs,	861 49	406 78	1,268 27
Library,	215 95	7 20	223 15
Tools, implements and machinery,	35 07	118 65	153 72
Furniture and fixtures,	71 10	6 70	77 80
Scientific apparatus,	29 96	28 59	58 55
Traveling expenses,	256 40	250 24	506 64
Contingent expenses,	12 73	1,087 85	1,100 58
Building and repairs,	29 36	838 08	867 44
Seeds, plants, etc.,	45 54		45 54
Live stock,	21 53		21 53
	$15,000 00	$11,826 73	$26,826 73

FINANCIAL STATEMENT, 1897-8.

A.—THE UNITED STATES APPROPRIATION FOR THE UNITED STATES FISCAL YEAR ENDING JUNE 30, 1898.

The Pennsylvania State College Agricultural Experiment Station, in account with the United States appropriation, 1898:

Dr.

To receipts from the Treasurer of the United States, as per appropriation for year ending June 30, 1898, under act of Congress approved March 2, 1887, ...	$15,000 00

Cr.

June 30.	By Salaries, ...	$12,243 17	
	Publications, ...	677 73	
	Postage, ...	121 33	
	Heat and light, ...	291 36	
	Chemical supplies, ...	609 84	
	Seeds, plants, etc., ...	56 95	
	Fertilizers, ...	43 49	
	Feeding stuffs, ...	139 55	
	Library, ...	274 03	
	Tools, implements, etc., ...	2 84	
	Scientific apparatus, ...	362 33	
	Live stock, ...	15 00	
	Traveling, ...	131 43	
	Contingent expense, ...	10 00	
	Buildings and repairs, ...	20 95	
			$15,000 00

State College, Pa., August 2, 1898.

We, the undersigned, duly appointed auditors of the Experiment Station accounts, do hereby certify that we have examined the books and accounts of the Agricultural Experiment Station of the Pennsylvania State College, for the fiscal year ending June 30, 1898; that we have found the same well kept and classified as above, and that the receipts for the year from the Treasurer of the United States are shown to have been $15,000.00 and the corresponding disbursements

$15,000.00, for all of which proper vouchers are on file and have been by us examined and found correct, thus leaving no balance to be accounted for in the fiscal year beginning July 1, 1898.

(Seal.)
GABRIEL HIESTER,
H. V. WHITE,
Auditors.

Attest: H. A. McElwain, Custodian.

B.—TOTAL RECEIPTS AND EXPENDITURES, ALL SOURCES, FOR THE YEAR ENDING JUNE 30, 1898.

RECEIPTS.

	United States appropriation account.	General account.	Total.
United States appropriation account,	$15,000 00		$15,000 00
Fertilizer analysis,		$9,500 50	9,500 50
Pennsylvania State College,		284 98	284 98
Live stock,		3,099 99	3,099 99
Seeds, etc.,		453 82	453 82
Excess of expenditures over receipts,		1,267 09	1,267 09
	$15,000 00	$14,606 38	$29,606 38

EXPENDITURES.

Salaries,	$12,243 17	$2,232 95	$14,476 12
Publications,	677 73	2,747 11	3,424 84
Postage and stationery,	121 33	409 31	530 64
Heat and light,	291 36	413 75	705 11
Chemical supplies,	609 84	1,207 41	1,817 25
Seeds, plants, etc.,	56 95		56 95
Fertilizers,	43 49	139 93	183 42
Feeding stuffs,	139 55	1,020 39	1,159 94
Library,	274 03	4 78	278 81
Tools, implements and machinery,	2 84	536 82	539 66
Scientific apparatus,	362 83		362 83
Live stock,	15 00		15 00
Traveling expenses,	131 43	234 59	366 02
Contingent expenses,	10 00	1,344 10	1,354 10
Building and repairs,	20 95	354 60	375 55
Labor,		3,937 99	3,937 99
Furniture and fixtures,		22 65	22 65
	$15,000 00	$14,606 38	$29,606 38

REPORT OF THE DIRECTOR.

The United States Department of Agriculture has requested that annual reports of the Stations be made for the United States fiscal year, ending June 30, instead of for the calendar year, in order to facilitate the auditing of the reports by that Department. Accordingly, the present report covers substantially the eighteen months ending June 30, 1898, and subsequent reports will be for the year ending June 30 in each case. This report, for 1897-8, therefore, immediately follows in the series that for 1896 and will be followed by that for 1898-9.

During the period covered by this report, the work of the Station, while there has necessarily been little or no enlargement of its scope, has gone steadily forward, and, if we may judge from the tenor of correspondence and the demand for Station publications, to the increasing satisfaction of the public.

In the last annual report, three general lines of Station activity were indicated, namely:

1. Soils and fertilizers.
2. Horticulture.
3. Stock feeding and dairy husbandry.

During the past year, the work of the Station has been grouped a little more distinctly about these three lines, although the income of the Station has not been sufficient to allow the work to be extended in proportion to the importance of these interests to the Commonwealth.

Soils and Fertilizers:—Under this heading, which may include also crops, the most prominent work of the Station, so far as amount of time occupied is concerned, has been the analysis of commercial fertilizers. This work, as in former years, has been done under contract with the State Department of Agriculture, the Department being responsible for the administration of the law and the selection of samples of fertilizers, while the Station has performed the analytical work. By the co-operation of these two agencies, the farmers of Pennsylvania are very thoroughly protected against fraud in the manufacture and sale of these important substances. Every brand of fertilizer sold in the State is analyzed, some of them several times, and the results are published and freely distributed for the information of all concerned. If a Pennsylvania farmer is defrauded in the purchase of his fertilizers, it is not because all necessary information regarding their quality is not abundantly provided by the State.

During the year, the usual number of tests of varieties of agricultural crops has been made. The results of these tests were promptly and widely distributed by means of newspaper bulletins and a fuller discussion of them was made in Bulletin No. 39, reprinted as part of this Report. They show a very marked difference in the productivity of the different varieties of wheat, oats and potatoes, and emphasize anew the fact that intelligent selection among varieties of plants is of just as great importance to the farmer as intelligent selection among breeds and strains of domestic animals.

The experiments with the several ingredients of commercial fertilizers, singly and combined, upon a rotation of standard crops have been continued upon the same plan as heretofore. These experiments have now entered upon their eighteenth year, and, so far as I know, cover a longer period of time than any similar experiments in this country.

The subject of the domestic production of sugar has recently attracted renewed attention, particularly with reference to the culture of the sugar beet. At the suggestion of the United States Department of Agriculture, co-operative experiments were undertaken in various parts of the State, the Department furnishing a supply of genuine seed and also appointing the Director of the Station a special agent of the Department for the investigation, thus giving the Station authority to use the franks of the Department for shipping samples to it for analysis. The records of nearly seventy specimens analyzed in this laboratory and that of the Department at Washington showed a very good average of quality and give every encouragement for further investigation into the capabilities of Pennsylvania as a sugar-producing State. Similar investigations, upon a much more extended scale, are now in progress, seed having been distributed to about 1,000 individuals in all parts of the State.

The experiments upon the culture of tobacco which have been carried on for several years past in Lancaster county have been continued under the same arrangement as for the two preceding years, namely, as a part of the work of the State Department of Agriculture under the immediate direction of the Experiment Station. Through the generosity of the same Department, similar work also has been continued in Bradford county.

Horticulture:—Besides tests of varieties of small fruits and other minor horticultural experiments at the College, the main work in horticulture has been an investigation of the apple industry of Pennsylvania, similar to the study of the peach industry whose results were published in Bulletin No. 37 and in the annual report for 1896. This work has been published as Bulletin No. 43 and is also included in the present report.

Stock Feeding and Dairy Husbandry:—The experiments upon the maintenance feeding of mature steers which have been in progress since 1892 and which were designed to secure data as to one of the fundamental questions of stock-feeding were continued during the first three months of 1897. The accumulated results of four seasons' work upon this subject, together with a summary of all available experiments elsewhere, have been reported in Bulletin No. 42. This Bulletin was purely technical in character, designed for students and investigators rather than for the farmer, and hence but a small edition of it was printed. It is reproduced in full as a supplement to this report, and a brief summary of its more important results has been included in the report itself.

An experiment upon the feeding of milch cows, designed to test the relative value of a narrow compared with a wide nutritive ratio, was carried out during the early part of the year. The conditions of the experiment were to all appearance unusually satisfactory, but the results were such as to make a repetition of the experiment seem desirable and a second experiment was therefore inaugurated as a check upon the results of the first. This has also been completed and both will be reported together at a later date.

An experiment designed to compare the value of two rather new feeds in our markets, namely, cerealine feed and dried brewers' grains, with that of buckwheat middlings, was carried on parallel with the experiment previously mentioned and the results published in Bulletin No. 41, which is also made part of this report.

In addition to feeding experiments, a number of tests of hand separators have been made, some investigations into the keeping qualities of milk have been carried out and also some interesting tests in dairy practice, of which may be mentioned particularly the use of pure cultures in commercial butter making and the pasteurizing of cream for butter making.

Limitations of Station Work:—From the day of its establishment, the Station has consistently maintained that its only hope of permanent success lay in specialization—in doing a few things well. Experimentation in agriculture, to yield results of any real value, must be done under absolutely comparable conditions and must take account of all the many influences which may affect its results. In other words, while practical in its aims, it must be scientific in its methods. Such experimenting is expensive. Consequently, the Station has not entered upon many lines of work which would unquestionably be of great value to the State, simply because it has not had the means to do the work properly. Even the comparatively few lines which it has taken up are capable of a much broader development than we have yet been able to give them. Thus, a broad, general study of the soils of the State and their agricultural capabilities is a very urgent need which the Station at present has no means of meeting except by dropping other equally important lines of work. Similarly, the very important horticultural capabilities of the State should be the subject of extensive and careful investigation. As already stated, the Station has made a beginning in this direction, but at present can move but slowly in the matter. In many other directions, it is compelled to do practically nothing. Thus, the very important subjects of market gardening and floriculture are scarcely touched at all by the work of the Station. The production of eggs and poultry in the State is estimated to be little if at all inferior to that of dairy products, yet not only has this important subject not been taken up to any extent by this Station, but the same is true of nearly every other Station in the country, there being but two or three exceptions. The subject of entomology, as related to useful and injurious insects, and that of the fungous diseases of plants, both of which cause enormous losses to the farmer, we are at present not prepared to study, and the same is true of the parallel subject of the diseases of animals.

The Future of the Station:—In the last report, it was pointed out that the income of the Station was derived from the bounty of the United States and from the funds which it earns, chiefly by the analysis of commercial fertilizers, and that the State has made no appropriation for the current work of the Experiment Station.

The appropriations by the State to the Experiment Station have been as follows:

Legislature of 1887,	$12,000
Legislature of 1889,	7,000
Legislature of 1893,	4,000
Total,	$23,000

Of these, the appropriation of 1887, which was for four years, was employed in the erection of the present Station building, and the appropriation of 1889 was a special appropriation for the enlargement of the farm buildings, while that of 1893 was an appropriation for co-operative tobacco experiments not located at the College. There has been no direct appropriation by the State for the current work of the Station.

In 1897 there were sixteen states whose station or stations received a total income of over $20,000. In these states, the percentage of the total income derived from the United States fund, from state funds and from fees and other sources was as shown in the following table. In the case of Kentucky, the amount of cash on hand is reported under the head of fees, so that the percentage derived from this source appears unduly large, and accordingly this state has been excluded in making up the average:

	Total income.	Percentages Derived From—			
		United States.	State.	Fees.	Sundries.
Alabama,	$30,730 88	48 81	47 96	....	3 23
California,	31,226 25	48 03	51 67	....	30
Connecticut,	35,932 97	41 74	39 79	$14 05	4 42
Kentucky,	22,758 27	65 92	....	25 73	8 35
Louisiana,	37,116 63	40 42	48 50	2 30	8 78
Massachusetts,	33,087 01	45 33	30 22	12 36	12 09
Minnesota,	28,904 27	51 89	34 68	....	13 43
Montana,	27,003 32	55 55	37 25	....	7 20
New Jersey,	30,000 00	50 00	50 00	....	....
New York,	115,001 15	13 05	84 58	....	2 37
North Carolina,	26,286 29	57 06	38 04	....	4 90
Ohio,	73,002 55	20 55	73 20	....	6 25
Pennsylvania,	26,826 73	55 90	....	31 83	12 27
Rhode Island,	21,500 34	69 76	13 28	....	16 96
West Virginia,	20,735 33	72 24	....	26 30	1 36
Wisconsin,	27,000 00	55 55	37 04	1 11	6 30
Average, excluding Kentucky,	$37,623 58	48 39	39 08	5 87	6 66

Several interesting comparisons may be drawn from the above table. It appears, for instance, that of these sixteen stations, there are but three, Kentucky, Pennsylvania and West Virginia, which do not receive a larger or smaller appropriation from the State for their current work. It further appears that in the fifteen states averaged, the average annual income was nearly $11,000 greater than in Pennsylvania; that of this greater income about 39 per cent. was derived from the state as compared with nothing in Pennsylvania, while, on the other hand, in these fifteen states, 5.87 per cent. of the average income was derived from fees, while the Pennsylvania Station earned over 31 per cent. of its income in this way. Making the same comparison with the three neighboring States of New Jersey, New York and Ohio, we have the following figures:

	Total income.	Percentages Derived From—			
		U. S. appropriation.	State.	Fees.	Sundries.
Average of New Jersey, New York and Ohio,	$72,667 90	27 87	69 26	....	2 87
Pennsylvania,	26,826 73	55 90	....	31 83	12 27

In these three States, the average amount expended upon agricultural experiment stations was about $46,000 greater than in Pennsylvania. Of this larger amount, the State furnished 69¼ per cent. as against nothing in Pennsylvania, while the Pennsylvania Station earned 31¾ per cent. of its income in the form of fees as against nothing in the other three States. As compared, then, with its neighboring

States or with the larger stations throughout the country, it is evident that the income of our own Station is considerably smaller in amount, and that a disproportionate part of it is derived from fees, while the State is making no appropriation in aid of this important work.

Undoubtedly the Station can do much work that will be of great value to the farming interests of the State if maintained upon its present basis, but with all these other lines of work opening before it and with the possibilities of material benefit to the agricultural interests of the Commonwealth which they present, it seems high time that the State should seriously consider the question of its policy toward its Experiment Station, and should determine whether it will ask its farmers to be satisfied with the present provisions for experiments in their interests or will supplement them by its own bounty. There can certainly be no question that a broad and liberal policy in this respect would yield a thousand fold return to the material interests of the Commonwealth.

Publications:—The demand for the reports and bulletins of the Station is steadily increasing, especially as a result of the presentation of its work at the farmers' institutes. During the past year, at least five thousand names have been added to the mailing list, which now amounts to considerably over twenty thousand names, and an average of seventeen requests for publications was received daily during the winter months. To supply this demand, the State prints eight thousand copies of the annual report of the Station, together with another eight thousand for the members of the Senate and House of Representatives, or sixteen thousand in all for distribution. The Station has been able hitherto to secure a considerable number of reports from the quotas of members of the Legislature, but even were the whole number printed at its disposal, it would be insufficient to supply the demand. The State makes no provision whatever for the publication of the bulletins of the Station. The cost of these, in the large editions required, is a very considerable drain upon the income of the Station. During the last session of the Legislature, an effort was made to secure the printing of these bulletins as public documents and also an increase in the number of annual reports printed, but both propositions were negatived, and, as a consequence, the Station has been obliged to refuse a large number of requests for its annual reports. It is most earnestly hoped that provision will be made by the State at an early day for the printing of information which is obtained and distributed at no expense to the Commonwealth.

THE COMPUTATION OF RATIONS FOR FARM ANIMALS.*

BY HENRY PRENTISS ARMSBY.

INTRODUCTION.

The investigations made by the Agricultural Experiment Stations of this and other countries during the last forty-five years have resulted in the accumulation of a large amount of valuable information regarding the scientific principles of stock feeding. Thanks to these investigations, it is now possible for the feeder, by consulting tables showing the composition and digestibility of feeding-stuffs and by making comparatively simple calculations, to adapt his rations with a considerable degree of accuracy to the purpose he has in view.

Such tables have been frequently published, but experience shows that; in most cases, even the more intelligent farmers do not find it easy to put them to practical use. The truth of this statement is shown not only by the correspondence which comes to the Station, but very strikingly by the numerous letters received by agricultural papers asking to have rations computed. Answers to inquiries of this sort have come to be a prominent feature in many such papers and are doubtless helpful to the inquirers. At the same time it is plain that on many accounts it would be far better for the farmer to make these computations for himself if possible, since he best knows the conditions which surround him, and is thus best fitted to adapt his rations to his conditions.

It is hoped that this publication will prove helpful to those who desire to compute rations for themselves. It does not purport to contain any information that has not been frequently published before, but consists simply of a brief outline of the general principles on which the computation of rations depends, followed by somewhat detailed illustrations of the method of solving some of the more important problems that arise in practice.

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*Reprinted from the Annual Report for 1896.

PART I.

GENERAL PRINCIPLES.

COMPOSITION OF ANIMALS.

The very large number of different substances found in the animal body may for our present purpose be grouped under four heads.

1. Water. This is one of the principal ingredients of the animal body, amounting to from 40 to 60 per cent. of the weight of the live animal.

2. Ash, or Mineral Matters. These amount to from 2 to 5 per cent. of the weight of the live animal. Their presence is most evident in the bones, but they exist also in small proportion in all parts of the body and are just as essential as any of the other ingredients.

3. Protein. A name given to an important group of substances of which washed lean meat or the white of egg may be taken as the type. They all contain about 16 per cent. of the element nitrogen, which is entirely lacking in the three other groups, and are remarkably similar in their general properties. The organic part of the bones, the ligaments and muscles which bind together and move the bones, the skin, the internal organs, the brain and nerves—in short, all the working machinery of the body—are composed very largely of protein. Consequently, this group of substances is of great importance, and a due supply of it in the food, particularly to growing animals, is indispensable.

4. Fat. This term needs no special explanation. The proportion of fat in the body varies greatly, but seldom falls below 6 or rises above 30 per cent.

The average composition of different animals in various stages of fattening is given in Table I of the Appendix (page 42).

COMPOSITION OF FEEDING-STUFFS.

In the various feeding-stuffs which serve to build up and maintain the animal body, we find the same four groups of ingredients which we do in the body of the animal, namely, water, ash, protein and fat. The individual substances which make up these groups differ more or less from those found in the body of the animal, but for our present purpose these differences may be regarded as of comparatively little importance.

In addition to these four groups, feeding-stuffs contain another group of substances, not found to any considerable extent in the body of the animal. This group is known as carbhydrates. The most familiar substances belonging to this group are starch, the various kinds of sugar and woody fibre. Starch being the most abundant of these in most foods, this class of substances is sometimes spoken of as starchy substances, but the technical name, "carbhydrates," is on the whole more accurate and expressive.

The following tabular statement may help to fix in the mind the statements which have just been made regarding the composition of animals and feeding-stuffs:

Ingredients of Animals.	Ingredients of Feeding-Stuffs.
1. Water.	1. Water.
2. Ash	2. Ash.
3. Protein.	3. Protein.
4. Fat.	4. Fat.
	5. Carbhydrates.

Table II (pages 43 and 44) of the appendix shows the average composition of a considerable number of American feeding-stuffs. In this table the common practice has been followed of dividing the group of carbhydrates into two portions. The "crude fibre," or "woody fibre," is stated separately, partly because it is thought to be of somewhat inferior nutritive value, and partly because it gives some indication of the bulkiness and woodiness of the feeding-stuff. The column headed "nitrogen free extract" includes all the carbhydrates except the crude fibre.

DIGESTIBLE MATTERS IN FEEDING-STUFFS.

It is plain that the value of any feeding-stuff will not depend simply upon the total amounts of these various ingredients which it contains, but also upon the proportion of them which the animal is able to digest and assimilate. In Table III (pages 45 and 46) of the appendix are given the percentages of digestible matter contained in the same list of feeding-stuffs which is given in Table II. The figures of Table III, consequently, indicate with a considerable degree of accuracy the relative values of the different feeding-stuffs, since they show to the best of our present knowledge the amount of real food which each one contains.

Table III also shows, in the first column, the percentage of total dry matter in each feeding-stuff. By dry matter is meant all of the feeding-stuff except water. Thus, the first feeding-stuff given in the table is stated to contain 20.3 per cent. of dry matter. This means that in every 100 pounds of this feeding-stuff there are 100—20.3=79.7 pounds of water and 20.3 pounds of solid matter. In other words, the percentage of water given in Table II and the percentage of dry matter given in Table III, when added together, equal 100.

The digestible carbhydrates and fats have been added together in Table III because they serve substantially the same purposes in nutrition, as explained in the next paragraph, and it, therefore, simplifies calculation to unite them.

USES OF INGREDIENTS OF FEEDING-STUFFS.

Having learned the amounts and proportions of digestible matters present in different feeding-stuffs, we next ask, what use does the animal make of these different substances?

Water we may leave out of account, because we do not use feeding-stuffs for the sake of the water which they contain.

Ash. The ash, or mineral matter, of feeding-stuffs serves as a source of supply for the mineral ingredients of the body. Under ordinary circumstances the supply of ash in the feeding-stuffs is amply sufficient for the needs of the body, and we need not concern ourselves regarding it. Occasionally, especially in feeding young animals or in cases where the ration consists very largely of grain, it is desirable to add precipitated chalk, wood ashes or precipitated phosphate of lime to the ration.

Protein. The protein of the food is used to build up and keep in repair the working tissues of the body, which, as we have seen, consist very largely of protein. In other words, we may say that protein supplies material for the growth of tissue. This growth of tissue may be an actual increase in bulk, as in the case of the growing animal; it may be simply the making good of waste, as in the mature animal; it may be the growth of wool or hair; or, finally, it may take the form of the production of milk, this being in reality the growth and breaking down of tissue in the udder. For all these purposes protein is indispensable, and its place cannot be taken by either carbhydrates or fat. If, however, more protein is given the animal than it needs for these various forms of tissue growth, the excess is burned up, like fat and carbhydrates, as explained below, or perhaps furnishes material for the production of fat.

Fat and Carbhydrates. The uses of these two classes of substances are so similar that they may be conveniently considered together. They serve three purposes. First, they are burned to produce the heat required to keep the animal warm. Second, they are burned to produce the force exerted in the motions of the animal, somewhat as coal is burned under the boiler of a locomotive. Third, if the supply of them is greater than is needed for the production of heat and force, the excess gives rise to the production and laying up of fat in the body. It is on account of this similarity in their uses that the digestible carbhydrates and fat have been united in Table III.

But while fat and carbhydrates have substantially the same uses in the body, a given weight of fat is worth more for this purpose than the same weight of carbhydrates. One pound of fat when burned will produce, in round numbers, 2¼ times as much heat as a pound of carbhydrates; consequently, fat is 2¼ times as valuable as carbhydrates for fuel in the animal body. The same relation holds between the two as force producers, and probably as fat producers.

For this reason, the digestible fat of the several feeding-stuffs of Table III has been multiplied by 2¼ before adding it to the carbhydrates. In other words, the column headed "carbhydrates and fat," really shows the number of pounds of carbhydrates which are equivalent to the fat plus carbhydrates actually present.

NUTRITIVE RATIO.

We have just seen that the protein of the food serves, in the main, a different purpose in the animal economy from carbhydrates and fat. The relative amounts of these in a given feeding-stuff are therefore important. This relation is expressed by what is called the "nutritive ratio," which means the ratio of digestible protein to digestible carbhydrates plus fat. Before making this comparison, however, we must, as just explained, multiply the fat by 2¼, since a pound of fat is 2¼ times as valuable as a pound of carbhydrates.

This multiplication having been already made in Table III (page 45), the nutritive ratio of any feeding-stuff in that table may be found by comparing the digestible protein with the digestible carbhydrates and fat. Thus, in the case of the first feeding-stuff, the ratio is 1.1 : 12.7.

For greater convenience in comparing one feeding-stuff with another, however, the first term of the ratio is usually taken as unity. We have, therefore, the following proportion:

$$1.1 : 12.7 :: 1 : 11.5.$$

The nutritive ratio is 1 : 11.5; that is, there are 11.5 pounds of digesible carbhydrates and fat present for every pound of digestible protein.

Nutritive ratios are spoken of as being "wide" or "narrow." A feeding-stuff with a wide nutritive ratio is one which contains a large proportion of carbhydrates and fat as compared with protein. A feeding-stuff with a narrow nutritive ratio is one which contains a small proportion of carbhydrates and fat as compared with protein. Thus, comparing the example just given with the nutritive ratio of cotton-seed meal, namely, 1 : 1.2, we should say that the soiling corn had a wide ratio and the cotton-seed meal a narrow ratio. Of course, the terms are relative. A ratio of 1 : 5 is a narrow ratio as compared with a ratio of 1 : 12, but is at the same time a wide ratio as compared with the ratio of 1 : 2.

PROPORTION OF PROTEIN NEEDED FOR DIFFERENT PURPOSES.

What has been said regarding the uses of the ingredients of feeding-stuffs makes it plain that the proportion of protein in the food (that is, the nutritive ratio) should vary according to the purpose of the feeding. If tissue is to be built up or repaired, that is, if we are feeding for growth or for milk production, we need sufficient protein to furnish the raw material for this production. If, on the other hand, we are feeding for the production of fat or of work, we simply need enough protein to keep the animal tissues in repair, while the remainder of the food may consist of carbhydrates and fat.

We may, therefore, divide the purposes for which farm animals are fed into two groups, as follows:

Requiring more Protein.	Requiring less Protein.
Growth.	Maintenance.
Milk production.	Fattening.
(Wool production.)	Work.

Feed for work is classified above as one of those purposes requiring less, rather than more, protein in the ration, it having been conclusively shown that the carbhydrates and fat of the food are practically the materials which furnish the force exerted by the working animal. At the same time, a working animal must have a well-developed muscular system, and this in turn requires a reasonable amount of protein for its support, so that the feeding of working animals in reality occupies an intermediate position between the two groups given above.

FEEDING STANDARDS.

The statement just made, however, is not sufficiently definite for the purposes of the stock feeder. He not only needs to know that for some purposes he must supply more protein than for others, but he must know also what proportion of protein to carbhydrates and fat (that is, what nutritive ratio) is best adapted for the purpose he has in view, and he must know also how much food he should give.

It is not yet possible to give an answer to these questions which will apply to every case. The proper ration will vary with the kind and quality of the animals fed and with the conditions under which they are fed, including financial conditions. There is no "best" ration for fattening or for milk production, any more than there is a "best" plow or a "best" plan for a barn.

In order, however, to supply a general guide, various investigators have condensed the results of experiments and of practical experience into what are called "feeding standards." Such a standard attempts to state what is, in general, and under average conditions, a good ration for the purpose in view. It shows what has given good results with other feeders, but it is not asserted that it is exactly adapted to the particular circumstances of each user. In other words, it is not a recipe, but a statement of experience.

Furthermore, in order not to limit the user to a few specific feeding-stuffs, the standard is expressed, not in pounds of grain and fodder, but in pounds of dry matter and of digestible protein, carbhydrates and fat. Thus, for a dairy cow weighing one thousand pounds, the standard recommended by one investigator is as follows:

Dry matter, ...	24.51 lbs.
Digestible protein, ...	2.15 lbs.
Digestible carbhydrates and fat, ...	14.94 lbs.
Total digestible matter, ...	17.09 lbs.
Nutritive ratio, ...	1 : 6.9

This means that any combination of suitable feeding-stuffs containing these amounts of dry matter and of digestible matters will be as good a ration as the average of the rations from which the standard was obtained, and will, therefore, correspond in essentials to the experience and practice of good dairymen. It does not mean that every dairy cow ought to be fed exactly such a ration as this, or that if she is the best results will be obtained. It is simply, as has already been said, the condensed result of experience.

In Table IV of the appendix (pages 47 and 48), are contained a number of feeding standards for various purposes, most of them based upon the writings of German authorities.

It is not proposed at this time to enter into the question of the sufficiency of these standards for the various purposes of feeding, or how they should be varied to suit different conditions. The consideration of these questions would involve an elaborate discussion of the whole science of feeding and would require a volume for its proper treatment. The purpose of the present publication is simply, as already stated, to help farmers to use the feeding standards we already have.

In regard to the standards given in the table for fattening cattle and sheep, however, it should be said that these standards were propounded at a time when protein was supposed to have a more intimate relation to the production of fat than is now believed to be the case. Both practical experience and direct experiments unite to show that under American conditions entirely satisfactory results may be attained with feeding standards having a much wider nutritive ratio than that recommended in Table IV. At the same time, these results have not yet been brought together in such a way as to permit a feeding standard to be deducted from them, like the one for dairy cows given above. The writer believes, however, that a nutritive ratio of 1 : 8 or 1 : 9 will be found quite as satisfactory for feeding fairly mature cattle or sheep as the narrower ration given in the table.

The standards given in the table are for animals weighing one thousand pounds. For heavier or lighter animals it is usual to increase or diminish the computed ration in proportion to the weight, although in practice the individuality of the animal will usually be a more important factor than the live weight.

USE OF FEEDING STANDARDS.

Granting that the experience of others, as expressed in a feeding standard, is worth following, we may avail ourselves of it with the aid of Table III of the appendix by the use of a little simple arithmetic. We have merely to devise a mixture out of the feeding-stuffs available which shall contain the amounts and proportions of digestible matter given in the standard, and which shall have a suitable bulk, as indicated by the amount of dry matter contained in it. When using such a mixture we shall know that we are following the general experience of good feeders. We shall not know that we are feeding the very best ration which could be used under our particular circumstances, but there is every probability that a ration computed in this manner will give much more satisfactory results than are obtained from the too common haphazard feeding based simply upon the feeding stuffs which happen to be at hand or upon the market price per ton.

The following pages are intended to explain and illustrate by examples the method to be followed in computing a ration corresponding to a given feeding standard, it being assumed that the standard itself is substantially correct.

PART II.

THE COMPUTATION OF RATIONS.

In Part I the general ideas upon which the use of feeding standards is based have been explained. We now proceed to take up the method of using these standards in practice.

The general problem is to devise a mixture of suitable feeding-stuffs which shall correspond in the amounts of dry matter and of digestible matters which it contains to some standard which has for one reason or another been fixed upon as suitable for the purpose in view. This is purely an arithmetical problem, requiring merely a knowledge of simple arithmetic, including percentage, and a little ingenuity. It is what the mathematician calls an "indeterminate" problem; that is, many mixtures of feeding-stuffs might be made, all of which would correspond to a given standard. Consequently, it is impossible to give any rule for the computation of rations in the same sense in which we can give a rule for computing interest. The problem can only be solved by trial, and the method of doing it is best explained by examples such as those which follow, which are designed to illustrate the principal points likely to come up. The reader is urged to perform each of these examples for himself as the quickest and surest means of acquiring proficiency.

COMPARISON OF A RATION WITH A STANDARD.

Some fattening steers, averaging one thousand pounds live weight, are being fed, per day and head,

12 pounds mixed hay.
14 pounds corn chop (corn-and-cob meal).

How does this ration compare with that recommended in Table IV (p. 47) for the main fattening period?

In order to make this comparison, we need to compute the total amount of dry matter and the amounts of digestible matter contained in the ration. According to Table III (p. 45), the foods used contain the following percentages of dry matter and digestible matter:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Per cent.	Per cent.	Per cent.	Per cent.	
Mixed hay,	85.7	4.7	42.7	47.4	1: 9.1
Corn-and-cob meal,	84.9	4.4	66.5	70.9	1:15.1

Taking first the hay, we multiply twelve pounds by the percentages of the various ingredients to find the number of pounds of each of these ingredients contained in the twelve pounds of hay, as follows:

Mixed Hay.

12 lbs. x .857=10.28 lbs of dry matter.
12 lbs. x .047= 0.56 lbs. of digestible protein.
12 lbs. x .427= 5.12 lbs. of digestible carbhydrates and fat.

Taking next the corn chop, we perform the same operations, as follows:

Corn-and-Cob Meal.

14 lbs. x .849=11.80 lbs. of dry matter.
14 lbs. x .044= 0.62 lbs. of digestible protein.
14 lbs. x .665= 9.31 lbs. of digestible carbhydrates.

Next, adding together the amounts of dry matter and digestible matter in the hay and the corn-and-cob meal, we have the total contained in the ration, which we may then compare with the standard:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs	
Twelve pounds mixed hay,	10.28	0.56	5.12	5.68	…………
Fourteen pounds corn-and-cob meal,	11.89	0.62	9.31	9.93	…………
Total,	22.17	1.18	14.43	15.61	1:12.2
Standard,	26.00	3.0	16.4	19.4	1: 5.5

This comparison shows us that our ration is considerably lower in total digestible matter than the standard, and that it is especially deficient in protein, the result being that its nutritive ratio is very wide as compared with that of the standard. As already explained, this does not prove that the ration is not a suitable one for the circumstances under which it is being used. It simply shows that it does not correspond with the experience and judgment of those who proposed this particular standard.

IMPROVEMENT OF A RATION.

A bunch of yearling steers, averaging five hundred pounds each, are receiving per day and head:

20 lbs. corn silage.
2 lbs. clover hay.
4 lbs. oats.
2 lbs. corn meal.

Is it desirable to make any change in the ration?

According to Table III (p. 45), the feeding-stuffs in use contain the following amounts of dry matter and digestible matter:

	Dry matter.	Digestible.			Nutritive ratio
		Protein.	Carbhydrates and fat.	Total.	
	Per cent.	Per cent.	Per cent.	Per cent.	
Corn silage,	27.9	1.1	18.2	19.3	1:16.5
Clover hay,	84.7	6.4	38.5	44.9	1: 6.0
Oats,	89.0	9.2	53.2	62.4	1: 5.8
Corn meal,	85.0	5.5	71.1	76.6	1:12.9

Making for each feeding-stuff exactly the same calculations as were given in detail in the preceding paragraph, we have the following results as compared with the standard.

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Twenty pounds corn silage,	5.58	0.22	3.64	3.86	....
Two pounds clover hay,	1.69	0.13	0.77	0.90	....
Four pounds oats,	3.56	0.37	2.13	2.50	....
Two pounds corn meal,	1.70	0.11	1.42	1.53	....
Total,	12.53	0.83	7.96	8.79	1: 9.6
Standard,	12.00	1.3	7.5	8.8	1: 6.0

We thus find that the total quantity of digestible matter which is being fed corresponds closely with the standard. The difference in the amount of dry matter is likewise immaterial. The amount of protein, however, is decidedly less than that recommended in the standard, and, consequently, the nutritive ratio is much wider. A reference to the composition of the feeding-stuffs shows us that the clover hay and oats have about the nutritive ratio of the standard, while the silage and the corn meal have a much wider ratio. Evidently, if it is desired to retain the silage in the ration, it will be necessary to replace some of the grain by something much richer in protein than either the oats or the clover. Running over the last column of Table III for such a feeding-stuff, that is, one with a narrow nutritive ratio, we find, among others, cotton-seed meal, having a very narrow ratio, the figures being as follows:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
Cotton-seed meal,	Per cent. 91.8	Per cent. 37.2	Per cent. 43.7	Per cent. 80.9	1:1.2

Replacing the two pounds of oats by the same amount of cotton-seed meal, we find that the ration stands as follows:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Twenty pounds corn silage,	5.58	0.22	3.64	3.86	....
Two pounds clover hay,	1.69	0.13	0.77	0.90	....
Two pounds oats,	1.78	0.18	1.06	1.24	....
Two pounds corn meal,	1.70	0.11	1.42	1.53	....
Two pounds cotton-seed meal,	1.84	0.74	0.87	1.61	....
Total,	12.59	1.38	7.76	9.14	1:5.6
Standard,	12.00	1.3	7.5	8.8	1:6.0

It is now rather better than the standard, and while it will cost a trifle more than the first ration, there is little question that it will be much better adapted to growing animals.

COMPUTATION OF A RATION FROM GIVEN FEEDING-STUFFS.

The following feeds are available for constructing a ration for dairy cows, to correspond with the so-called "Wisconsin" standard (p. 47):

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Per cent.	Per cent.	Per cent.	Per cent.	
Corn forage,	57.8	2.5	36.1	38.6	1:14.4
Clover hay,	84.7	6.4	38.5	44.9	1: 6.0
Corn meal,	85.0	5.5	71.1	76.6	1:12.9
Wheat bran,	88.1	12.0	45.4	57.4	1: 3.8
Gluten feed,	91.7	19.4	63.3	82.7	1: 3.3

The first step in the construction of a ration is to fix upon the amounts of coarse fodders. It is usually desirable to use as large a proportion of these as possible, since they are usually cheaper sources of food than grain. On the other hand, the amount of them which an animal can consume is limited. Much depends upon the individual animals, and the proper amount can only be told by trial. We need, according to the standard selected, a total of about 24.5 pounds of dry matter. Of this we should probably aim to get from fourteen to sixteen pounds in the form of coarse fodder. Corn forage being a cheap feeding-stuff, we shall naturally use this freely, with probably some hay for variety. By a little trial, we find that fourteen pounds of corn forage and eight pounds of clover hay will give us nearly fifteen pounds of dry matter and the amounts of digestible matter shown below:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Fourteen pounds corn forage,	8.09	0.35	5.05	5.40	....
Eight pounds clover hay,	6.78	0.51	3.08	3.59	....
Total,	14.87	0.86	8.13	8.99	1:9.5

To this we have to add sufficient grain to bring the ration up to the standard. The proper amount we must ascertain by trial. We will take at a venture six pounds of corn meal and three pounds of wheat bran. Adding this to the ration we have:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Fourteen pounds corn forage,	8.09	0.35	5.05	5.40	....
Eight pounds clover hay,	6.78	0.51	3.08	3.59	....
Six pounds corn meal,	5.10	0.33	4.27	4.60	....
Three pounds wheat bran,	2.64	0.36	1.36	1.72	....
Total,	22.61	1.55	13.76	15.31	1:8.9

Comparing these figures with the standard, we find that the ration is somewhat deficient in quantity, and that its nutritive ratio is considerably too wide. In the list of feeding-stuffs availabe we see that the gluten feed is the one containing the largest proportion of digestible protein, and, since our ration lacks protein, we naturally make trial of this. We need 1.79 pounds of total digestible matter to bring the ration up to the standard. This would be almost exactly supplied by two pounds of gluten feed. Adding this to the ration, it stands as in the following table:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Fourteen pounds corn forage,	8.09	0.35	5.05	5.40	....
Eight pounds clover hay.	6.78	0.51	3.08	3.59	....
Six pounds corn meal,	5.10	0.33	4.27	4.60	....
Three pounds wheat bran,	2.64	0.36	1.36	1.72	....
Two pounds gluten feed,	1.83	0.39	1.27	1.65	....
Total,	24.44	1.94	15.03	16.96	1:7.7

We now have the total amount of digestible matter right, but the nutritive ratio is still too wide. Evidently we need to use less corn and more bran and gluten feed. Reducing the corn meal by two pounds, and adding one pound for each of bran and gluten feed, we have the following:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Fourteen pounds corn forage,	8.09	0.35	5.05	5.40	....
Eight pounds clover hay,	6.78	0.51	3.08	3.59	....
Four pounds corn meal,	3.40	0.22	2.84	3.06	....
Four pounds wheat bran,	3.52	0.48	1.82	2.30	....
Three pounds gluten feed,	2.75	0.58	1.90	2.48	....
Total,	24.54	2.14	14.69	16.83	1:6.9

The computed nutritive ratio now corresponds almost exactly with the standard. The total digestible matter is a trifle low, but the difference is too small to be significant.

By proceeding in this manner, with a little patience we can usually get a ration corresponding as closely as is necessary to the standard, provided the feeds available admit of it. With a little experience one very soon learns to guess pretty closely, and with some practice finds the computations very easy. An exact agreement with the standard need not be sought for, since in practice the composition of the feeds will probably vary more or less from the average of the tables, while the amount which the animal will eat will probably also vary more or less from that computed for them.

THE SELECTION OF FEEDING-STUFFS.

In the selection of feeding-stuffs, one of the most frequent and important questions which arises is, which of several feeding-stuffs at given prices is really the cheapest. A simple example will serve to illustrate this: A farmer has more hay on hand than he needs; shall he sell timothy hay at $12 per ton, or clover hay at $8? In other words, does the higher market price of timothy hay mean that it has a correspondingly higher feeding value? From Table III (p. 45), we have the following figures for the actual amounts of food contained in the two:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Per cent.	Per cent.	Per cent.	Per cent.	
Timothy hay,	86.8	2.9	46.9	49.8	1:16.2
Clover hay,	84.7	6.4	38.5	44.9	1: 6.0

We find that timothy hay does contain more total food than clover hay, but that the difference is not at all proportionate to the difference in price. From the amounts of digestible matter contained in one hundred pounds, with the prices for the same amount, it is easy to calculate the cost of one pound of digestible matter in each, as follows:

Timothy Hay.

100 lbs. contain 49.8 lbs. digestible matter, and cost 60 cents.
60 cents÷49.8=1.205 cents, cost of 1 lb. of digestible matter.

Clover Hay.

100 lbs. contain 44.9 lbs. digestible matter, and cost 40 cents.
40 cents÷44.9=0.891 cents, cost of 1 lb. of digestible matter.

We thus see that the clover hay, at the assumed price, is a much cheaper source of food than the timothy. The latter has a relatively high market price, owing to the special demand for it for feeding horses. Moreover, the clover is not only cheaper source of food, but is also much richer in protein, which is usually the most expensive ingredient of feeding-stuffs, either to produce or to buy. The relative fertilizing value of the timothy and clover would also enter into a consideration of the question of their sale, but this branch of the subject will be considered in a subsequent section.

More commonly the question is a question of the choice of grain feeds. For example, the following feeds are available to a dairy farmer:

Oats, ...	@$15 per ton (24c. per bu.).
Wheat bran, ...	@ 14 per ton.
Wheat middlings, ...	@ 16 per ton.
Hominy chop, ...	@ 14 per ton.
Dried brewers' grains, ...	@ 14 per ton.
Gluten feed, ...	@ 17 per ton.
Cotton-seed meal, ...	@ 20 per ton.
Old process linseed meal,	@ 18 per ton.

The prices given above have been assumed arbitrarily and do not purport to represent present market prices, but have been chosen to illustrate the principles involvd.

The first step is to see how much the actual food, that is, the digestible matter, of these feeding-stuffs costs. Taking the percentages of total digestible matter from Table III (p. 45), and the prices as given above, and dividing the second by the first exactly as in the illustration with the timothy and clover hay, we get the following:

	Digestible matter in 100 lbs.	Cost of 100 lbs.	Cost of 1 lb. of digestible matter.
	Lbs.	Cents.	Cents.
Oats, ...	62.4	75	1.202
Wheat bran, ...	57.4	70	1.219
Wheat middlings, ...	73.7	80	1.085
Hominy chop, ...	86.6	70	0.808
Dried brewers' grains, ...	63.5	70	1.102
Gluten feed, ...	82.7	85	1.028
Cotton-seed meal, ...	80.9	1.00	1.236
Linseed meal (old process), ...	77.8	90	1.157

From the figures in the last column of the above table we see that hominy chop is relatively the cheapest of these foods. Feeds like oats and wheat bran are excluded as too costly at these prices, although when the market for them rules lower they might be preferred.

We will assume that the coarse fodder on hand is sufficient to give each animal per day and head the amounts stated in the previous section, namely, fourteen pounds corn forage and eight pounds clover hay. With these amounts we should have the following ration:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Fourteen pounds corn forage,	8.09	0.35	5.05	5.40	....
Eight pounds clover hay,	6.78	0.51	3.08	3.59	....
Four pounds corn meal,	3.40	0.22	2.84	3.06	....
Total,	18.27	1.08	10.97	12.05	1:10.2

The rest of the feed required must be bought. It it were simply a question of the quantity of digestible matter needed, hominy chop would evidently be our first choice. We must consider, however, not only the total amount of feed, but also the nutritive ratio. When we take this into consideration, it is evident that we shall have to use some of the feeds richer in protein (the last four in the list) in order to "balance up" the ration, even though they are relatively more expensive, and very likely we shall find that we cannot use the hominy chop to any considerable extent in addition to corn meal. The most promising feeds for balancing up the ration appear to be dried brewers' grains and gluten feed, since they furnish food at a less cost per pound than cottom-seed or linseed meal.

To bring our ration up to the standard we still need 1.12 pounds of protein. This would be supplied, according to Table III, by about 5.5 pounds of gluten feed, or by 6.8 pounds of dried brewers' grains. The former being the cheaper source of food, we will try it. Experience shows, however, that we shall need to feed with it some laxative food in order to keep the cattle in proper condition. Linseed meal will probably answer this purpose, with the added advantage that we could reduce the quantity slightly and still get the amount of protein desired. Let us try four pounds of gluten feed and one pound of linseed meal. This gives us the following ration:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Total as above,	18.27	1.08	10.97	12.05	....
Four pounds gluten feed,	3.67	.78	2.53	3.31	....
One pound linseed meal,	.91	.29	.49	.78	....
Total,	22.85	2.15	13.99	16.14	1:6.5

This gives us the desired amount of protein, but the carbhydrates and fat, and, therefore, the total digestible matter, are still below the standard. Adding a pound of hominy chop to bring up the carbhydrates and fat, makes our ration stand as follows:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Fourteen pounds corn forage,	8.09	0.35	5.06	5.40	....
Eight pounds clover hay,	6.78	0.51	3.08	3.59	....
Four pounds corn meal,	3.40	0.22	2.84	3.06	....
Four pounds gluten feed,	3.67	0.78	2.53	3.31	....
One pound linseed meal,	0.91	0.29	0.49	0.78	....
One pound hominy chop,	0.88	0.07	0.80	0.87	....
Total,	23.73	2.22	14.79	17.01	1:6.7

Our ration now corresponds substantially with the standard, but it is still a question whether we have made it up in the cheapest way possible. To test this, we may calculate the cost of one pound of digestible matter in the mixture of grains purchased, as follows:

	Digestible matter.	Cost.
	Lbs.	Cents.
Four pounds gluten feed,	3.31	3.40
One pound linseed meal,	0.78	0.90
One pound hominy chop,	0.87	0.70
Total,	4.96	5.00

One pound of digestible matter costs 5.00 cents ÷ 4.96=1.008 cents.

We find that one pound of digestible matter costs us 1.008 cents, which is cheaper than we could buy it in the form of dried brewers' grain, and the latter are thereby excluded from consideration. There is still a possibility, however, that by using more of the cheaper foods, such as hominy chop, and balancing up the ration with a relatively small amount of linseed meal, we can make a still cheaper combination. By a little trial we find that three pounds of hominy chop and three pounds of linseed meal will also give us a ration corresponding quite closely to the standard, as follows:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Fourteen pounds corn forage,	8.09	0.35	5.06	5.40	....
Eight pounds clover hay,	6.78	0.51	3.08	3.59	....
Four pounds corn meal,	3.40	0.22	2.84	3.06	....
Three pounds hominy chop,	2.65	0.21	2.29	2.60	....
Three pounds linseed meal,	2.72	0.88	1.45	2.33	....
Total,	23.64	2.17	14.81	16.98	1:6.8

Computing as before the cost of a pound of digestible matter in the grain purchased, we have the following figures:

	Digestible matter.	Cost.
	Lbs.	Cents.
Three pounds hominy chop,	2.60	2.10
Three pounds linseed meal,	2.33	2.70
Total,	4.93	4.80

One pound of digestible matter costs 4.80 cents ÷ 4.93= 0.98 cents.

We find that, notwithstanding we have used three pounds of the relatively expensive linseed meal instead of one, we have really secured a balanced ration at a slightly less cost than in the first case. The difference is not large, but it serves to illustrate the general principle that it is often cheaper to use a small quantity of a comparatively expensive feed to balance up the ration than to use a much larger quantity of a relatively cheaper feed. It is not unlikely that a still cheaper combination might be made by using cotton-seed meal instead of linseed meal, but it is doubtful whether the use of cotton-seed meal would be advisable unless silage, bran or some other laxative feed could be used with it.

This suggests the fact that other consideration than that of relative cost enter into the question of the selection of feeding stuffs.

The palatability of a material, its general healthfulness or any specific effects which it is known to have on the animal or on the flavor or appearance of the product, must all be taken into account. A consideration of these points in this connection, however, would lead us aside from our present purpose, which is to show how the market price should affect our choice.

PLANNING A SEASON'S FEEDING.

The amount of feed on hand, as well as what can be bought and the state of the markets, enters as an important factor into the fixing of the ration. The following comparatively simple case may serve to illustrate the method of attacking the problem. As in the previous illustration, the prices of feeding-stuffs have been arbitrarily assumed and do not necessarily correspond to present market rates.

Thirty dairy cows, averaging one thousand pounds each, are to be fed for two hundred days. We have on hand:

20 tons timothy hay, ...	@$12 00 per ton.
10 tons clover hay, ...	@ 8 00 per ton.
10 tons corn stover, estimated at, ...	3 00 per ton.

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100 tons corn silage, estimated at, ...	$1 50	per ton.
800 bushels corn ears, ...@	14	per bu.
400 bushels oats, ...@	24	per bu.

We can buy:

Wheat bran, ...@	$12 00	per ton.
Wheat middlings, ...@	14 00	per ton.
Hominy chop, ...@	14 00	per ton.
Buckwheat middlings, ...@	15 00	per ton.
Old process linseed meal, ...@	18 00	per ton.
Cotton-seed meal, ...@	19 00	per ton.

Thirty cows for 200 days is equivalent to 1 cow for 6,000 days. The amounts of feed on hand, then, would enable us to feed per day and head the amounts given below. To facilitate comparison, the corresponding amount of dry matter, computed from the figures of Table III (p. 45), is also given in each case.

	Total weight.	Dry matter.
	Lbs.	Lbs.
Timothy hay,	6.67	5.79
Clover hay,	3.33	2.82
Corn stover,	3.33	1.99
Corn silage,	33.33	9.30
Total coarse fodder,	46.67	19.90
Corn ears (35 lbs. to the bushel),	4.67	3.96
Oats (32 lbs. to the bushel),	2.13	1.90
Total grain,	6.80	5.86

We find that we have rather more than enough dry matter to make up a standard ration, but that a relatively large proportion of this is in the form of coarse fodder. If, as in the previous case, we assume that we can use to advantage from fourteen to sixteen pounds of dry matter in the ration in the form of coarse fodder, we have more coarse fodder than is necessary. Under these circumstances a comparison of the cost per pound of digestible matter, as given in the following table, shows us at once that we can profitably sell timothy hay:

	Digestible matter in 100 lbs.	Cost of 100 lbs.	Cost of 1 lb. of digestible matter.
	Lbs.	Cents.	Cents.
Timothy hay,	49.8	60	1.205
Clover hay,	44.9	40	0.891
Corn stover,	36.8	15	0.408
Corn silage,	19.3	7½	0.389
Corn ears (corn-and-cob meal),	70.9	40	0.561
Oats,	62.4	75	1.202
Wheat bran,	57.4	60	1.045
Wheat middlings,	73.7	70	0.950
Hominy chop,	86.6	70	0.808
Buckwheat middlings,	74.2	75	1.011
Old process linseed meal,	77.8	90	1.157
Cotton-seed meal,	80.9	95	1.174

If we were to sell all the timothy we should reduce our stock of coarse fodder rather low, but at the prices given it is not unlikely that even this would be economy, since the hay could be replaced by relatively cheap grain. We will suppose, however, that we can buy clover hay. We accordingly buy five tons of the latter and sell all the timothy.

20 tons of timothy hay at $12,	$240 00
5 tons of clover hay at $8,	40 00
Balance,	$200 00

We should then have the following stock of coarse fodder per day and head:

	Total weight.	Dry matter.
	Lbs.	Lbs.
Clover hay,	5.00	4.24
Corn stover,	3.33	1.99
Corn silage,	33.33	9.30
Total coarse fodder,	41.66	15.53

Turning now to the question of grain, we find that we have too little, but we note also that the oats at 24 cents are a much more expensive feed than any other of the grains available. It will, therefore, be economy to sell the oats and use the money to buy something cheaper.

Balance from sale of timothy hay,	$200 00
400 bushels oats at 24 cents,	96 00
Balance available for purchase of grain,	$296 00

We have now to determine what shall be purchased. The feed we have on hand will give us the following ration:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Five pounds clover hay,	4.23	0.32	1.93	2.25	....
Three and one-third pounds corn stover,	1.99	0.07	....	1.23	....
Thirty-three and one-third pounds corn silage,	9.30	0.37	6.07	6.44	....
Four and two-thirds pounds corn-and-cob meal,	3.96	0.20	3.11	3.31	....
Total,	19.48	0.96	12.27	13.23	1:12.8
Lacking to make up Wisconsin standard,	5.02	1.24	2.63	3.87	1: 2.1

In order to bring the above ration up to the Wisconsin standard we need 3.87 pounds of total digestible matter, with a nutritive ratio of 1: 2.1. Consulting Table III (p. 45), we find that of the feeds available, buckwheat middlings has about the proper ratio. Before deciding on this, however, it will be well to see whether, as in a former case, a still cheaper source of feed may not be found in a mixture of hominy chop and linseed or cotton-seed meal. By trial we find that a mixture of four pounds of linseed meal and one pound of hominy chop gives about the ratio of 1:2.1. Computing the cost of digestible matter in this mixture as compared with that in buckwheat midlings, we have the following:

	Digestible matter.	Cost.	Cost of 1 lb. of digestible matter.
	Lbs.	Cents.	
Four pounds linseed meal,	3.112	3.60	....
One pound hominy chop,	.866	0.70	....
Total,	3.978	4.30	1.081
Buckwheat middlings,	....	....	1.011

A slightly cheaper mixture might be made with cotton-seed meal, but it would still be excelled by the buckwheat middlings.

The buckwheat middlings thus proving to be the cheapest, we proceed to make up the ration with them. We lack 3.87 pounds of digestible matter as compared with the standard. This would be almost supplied in five pounds of buckwheat middlings. Adding this, we have the following:

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Five pounds clover hay,	4.23	0.32	1.93	2.25	....
Three and one-third pounds corn stover,	1.99	0.07	1.16	1.23	....
Thirty-three and one-third pounds corn silage,	9.30	0.37	6.07	6.44	....
Four and two-thirds pounds corn-and-cob meal,	3.96	0.20	3.11	3.31	....
Five pounds buckwheat middlings,	4.34	1.19	2.52	3.71	....
Total,	23.82	2.15	14.79	16.94	1:6.9

The ration now corresponds almost exactly to the standard except that the dry matter is a little low. This means that the ration contains a rather large proportion of grain to coarse fodder. If we could get more clover hay, it would probably be advisable to increase the amount of it in the ration somewhat and decrease that of the grain, provided the cows would eat a larger amount of coarse fodder. A glance at our table of the cost of feeding-stuffs shows us that it would not pay to retain any of the timothy hay for this purpose.

Five pounds of buckwheat middlings per day for 30 cows and for 200 days equals 30,000 pounds, or 15 tons, so that our account of receipts and expenditures will stand as follows:

Net receipts from sales of hay and oats, ...	$296 00
15 tons buckwheat middlings at $15, ...	225 00
Balance on hand, ...	$71 00

By thus virtually exchanging feeding-stuffs, we have secured a fairly well-balanced ration for our cows and have $71.00 in cash left.

This statement, however, does not take account of one very important matter, namely, the fertilizing value of the feeds bought and sold. From the figures given in Table V (pages 49 and 50) of the appendix, we can make up the following balance sheet for the fertilizing ingredients sold and bought.

	Nitrogen.	Phosphoric acid.	Potash.
	Lbs.	Lbs.	Lbs.
Sold off the farm—			
Twenty tons of timothy hay, ...	504	212	360
Four hundred bushels of oats, ...	264	105	79
Total, ...	768	317	439
Brought on the farm—			
Five tons clover hay, ...	207	38	220
Fifteen tons buckwheat middlings, ...	1,386	519	468
Total, ...	1,593	557	688
Gain, ...	825	240	249
Value of gain, ...	$99 00	$9 60	$14 45

According to this statement, there would result from the buying and selling of feed a gain of fertility which, if purchased in the form of commercial fertilizers, would cost about $123.05. Adding this to the $71.00 saved in cash makes a total gain of $194.05.

The final gain or loss of fertility to the farm would, of course, depend also upon the amount of nitrogen, phosphoric acid and potash removed in the dairy products sold. Taking the most unfavorable case, viz: that in which the whole milk is sold, and assuming that our cows average 6,000 pounds of milk each per year, the loss of fertility in the milk will compare with that gained in the feeding-stuffs as follows:

	Nitrogen.	Phosphoric acid.	Potash.
	Lbs.	Lbs.	Lbs.
Sold in the milk,	94	342	324
Gained in feeding-stuffs,	825	240	249
Net loss from farm,	129	102	75
Value of net loss,	$15 48	$4 08	$3 75

The fertility gained by the purchase and exchange of feeding-stuffs proves to be almost sufficient to replace the whole amount sold in the milk during the entire year, the difference amounting to only $23.31.

Moreover, the greater part of this difference falls on the nitrogen, and the loss of this element could probably be more than made good by the growth of leguminous crops, thus leaving an insignificant amount of phosphoric acid and potash to be replaced.

If the milk were manufactured on the farm and part or all of its bye-products utilized, the export of fertility would be largely decreased and the farm would be gaining in fertility.

Starting, then, with a supply of feeding-stuffs about sufficient in amount but poorly proportioned, we have been able, by judicious "swapping," to make up a good ration and at the same time save $71.00 in cash, besides securing sufficient fertility to almost make good the loss resulting from the sale of milk during the entire year.

The conditions of the above problem have purposely been assumed to be very simple, there being supposed to be only one kind of stock, which is fed the same ration throughout the season. These simple conditions have been assumed for the sake of more clearly illustrating the method of solving such a problem.

If it were thought desirable, the several feeding-stuffs available could, of course, be made into two or three different rations upon the same principle, while, in case several kinds of stock are kept, the feeding-stuffs on hand could first be approximately divided between them in accordance with their special requirements and then computations similar to the above made for each kind of stock. A firm grasp of the principles involved, together with some practice, will soon enable one to plan his season's feeding with a very good degree of accuracy and often, as in the above case, at a considerable saving of dollars and cents.

THE COMPOUNDING OF RATIONS.

The figures given above for the various rations are not intended to suggest that each day's ration ought to be laboriously weighed out to each animal. Having fixed upon the ration, the most satisfactory plan is usually to mix the grain ration in considerable quantity in advance. Thus, in the case given, we should mix, say,

467 pounds corn-and-cob meal and
500 pounds buckwheat middlings,

or as many times that quantity as might be practicable.

Then, if the grain is to be fed twice per day in equal quantities, we should weigh out the half ration of 4.8 pounds a few times until we came to know about the proper bulk, and should then feed from the mixture by measure. This, with a little practice, can be done very accurately. We should also naturally vary the total amount fed to each cow according to her capacity as a milk producer.

The coarse fodder we should distribute between the different feedings according to our best judgment. We might, for example, feed one-half the silage after milking in the morning, the hay at noon, the remaining half of the silage after milking at night, and the stover (cut) the last thing at night. The amount of coarse fodder given will naturally be regulated by the appetite of the animals, but the feeder should know approximately how much his animals will eat in order to have a basis for his computation of rations. A few weighings of coarse fodder when practicable will be of much help in enabling one to judge more accurately of the quantity eaten, and will often reveal striking errors in one's estimate of it.

PART III.

THE FERTILIZING VALUE OF FEEDING-STUFFS.

Since all feeding-stuffs contain greater or less quantities of the three elements which give their commercial value to fertilizers, namely, nitrogen, phosphoric acid and potash, and since all of these substances or a very large percentage of them is recovered in the manure of the animals fed, it is plain that when we buy feeding-stuffs we also buy fertility and, on the other hand, when we sell feeding-stuffs, or in fact any crops, we sell fertility also. An important factor in judging of the economy of a feeding operation is the resulting gain or loss of fertility from the farm. In Table V (pp. — to —) of the appendix, is given a statement, first of the number of pounds of nitrogen, phosphoric acid and potash contained in the several feeding-stuffs whose composition has been given in Tables II and III, and, second, a statement of the money value of the fertility in a ton of each material, assuming nitrogen to be worth 12 cents per pound, phosphoric acid 4 cents and potash 5 cents. These values are somewhat arbitrarily assumed, since we have no satisfactory basis for fixing their commercial value, but they may, without serious error, be assumed to represent the commercial value of fertilizers of equal availability. That is, the valuations in the table mean that, for example, the nitrogen, phosphoric acid and potash removed from the farm in a ton of winter wheat could be replaced in the form of commercial fertilizers of about the same availability for approximately $6.99.

The example given on page 38 will serve to illustrate the manner of using these figures in connection with the computation of rations. The fertilizing value of feeds will seldom be the primary element determining their choice, but before a ration or a plan of feeding is finally decided upon it is always desirable to compute its effect upon the farm's stock of fertility. Oftentimes, a slight change in the ration may make a very material difference in this respect at very slight expense, and the choice between two feeding-stuffs may often be determined when in doubt by reference to their fertilizing value.

APPENDIX.

TABLE I.

PERCENTAGE COMPOSITION OF LIVE ANIMALS.

	Ox.			Fat calf.	Sheep.					Swine.	
	Well fed.	Half fat.	Fat.		Lean.	Well fed.	Half fat.	Fat.	Very fat.	Well fed.	Fat.
	Per cent.	Per cent.	Per cent.	Per cent	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Water,	54.3	50.2	43.6	60.1	56.6	53.7	50.7	44.8	39.0	53.9	42.0
Ash,	4.8	4.4	3.9	4.5	3.4	3.3	3.2	2.9	2.8	2.7	1.8
Fat,	7.1	14.9	26.8	13.1	8.6	13.2	18.3	28.1	37.2	22.5	40.2
Protein,	15.8	15.5	13.7	15.3	15.4	14.8	13.8	12.2	11.0	13.9	11.0
Contents of stomach and intestine,	18.0	15.0	12.0	7.0	16.0	15.0	14.0	12.0	10.0	7.0	5.0
Total,	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE II.

AVERAGE COMPOSITION OF FEEDING-STUFFS.

From Jenkin's & Winton's compilation (O. E. S. Bulletin No. 11) except as otherwise noted.

	Number of analyses.	Percentage Composition					
		Water.	Ash.	Protein.	Crude fibre.	Nitrogen-free extract.	Fat.
SOILING FODDER.							
Corn—dent, cut before glazing,	54	79.7	1.2	1.7	5.4	11.5	0.5
Cow pea,	10	83.6	1.7	2.4	4.8	7.1	0.4
Oats,	5	62.2	2.5	3.4	11.2	19.3	1.4
Red clover,	43	70.8	2.1	4.4	8.1	14.8	1.1
Rye,	6	82.0	1.6	2.4	4.8	8.5	0.7
Soja bean,	6	74.8	2.4	3.0	7.3	11.5	1.0
SILAGE.							
Corn silage—kernels glazing or more mature,*	14	72.1	1.4	2.1	6.7	16.4	1.3
Red clover,	5	72.0	2.6	4.2	8.4	11.6	1.2
HAY, STRAW, ETC.							
Alfalfa hay,	21	8.4	7.4	14.3	25.0	42.7	2.2
Corn forage—field cured,	35	42.2	2.7	4.5	14.3	34.7	1.6
Corn stover†—field cured,	60	40.1	3.4	3.8	19.7	31.9	1.1
Clover hay—red,	38	15.3	6.2	12.3	24.8	38.1	3.3
Millet hay,	12	7.7	6.0	7.5	27.7	49.0	2.1
Mixed hay,	....	14.3	5.3	9.1	26.9	41.5	2.9
Oat straw,	12	9.2	5.1	4.0	37.0	42.4	2.3
Orchard-grass hay,	10	9.9	6.0	8.1	32.4	41.0	2.6
Red-top hay,	9	8.9	5.2	7.9	28.6	47.5	1.9
Rye straw,	7	7.1	3.2	3.0	38.9	46.6	1.2
Timothy hay,	68	13.2	4.4	5.9	29.0	45.0	2.5
Wheat straw,	7	9.6	4.2	3.4	38.1	43.4	1.3
ROOTS AND TUBERS.							
Carrots,	8	88.6	1.0	1.1	1.3	7.6	0.4
Mangel wurzels,	9	90.9	1.1	1.4	0.9	5.5	0.2
Potatoes,	12	78.9	1.0	2.1	0.6	17.3	0.1
Rutabagas,	4	88.6	1.2	1.2	1.3	7.5	0.2
Sugar beets,	19	86.5	0.9	1.8	0.9	9.8	0.1
Turnips,	3	90.5	0.8	1.1	1.2	6.2	0.2
GRAIN.							
Barley,	10	10.9	2.4	12.4	2.7	69.8	1.8
Buckwheat,	8	12.6	2.0	10.0	8.7	64.5	2.2
Corn—dent,	86	10.6	1.5	10.3	2.2	70.4	5.0
Corn—flint,	68	11.3	1.4	10.5	1.7	70.1	5.0
Corn—sweet,	26	8.8	1.9	11.6	2.8	66.8	1.8
Oats,	30	11.0	3.0	11.8	9.5	59.7	5.0
Peas,	....	14.4	2.7	22.6	5.4	53.0	1.9
Rye,	6	11.6	1.9	10.6	1.7	72.5	1.7
Sorghum seed,	10	12.7	2.1	9.0	2.6	70.0	3.6
Wheat—spring,	13	10.4	1.9	12.5	1.8	71.2	2.2
Wheat—winter,	262	10.5	1.8	11.8	1.8	72.0	2.1
Wheat—winter, raised in Pennsylvania,	41	10.7	1.6	11.8	1.7	72.2	2.0
MILL PRODUCTS.							
Barley meal,	3	11.9	2.6	10.5	6.5	66.3	2.2
Buckwheat middlings,	3	13.2	4.8	28.9	4.0	42.0	7.1
Corn meal,	77	15.0	1.4	9.2	1.9	68.7	3.8
Corn-and-cob meal,	7	15.1	1.5	8.5	6.6	64.8	3.5
Pea meal,	2	10.5	2.6	20.2	14.4	51.1	1.2
Rye bran,	7	11.6	3.6	14.7	3.5	63.8	2.8
Wheat bran,	88	11.9	5.8	15.4	9.0	53.9	4.0
Wheat middlings,	32	12.1	3.3	15.6	4.6	60.4	4.0
Wheat shorts,	12	11.8	4.6	14.9	7.4	56.8	4.5
BYE-PRODUCTS AND WASTE MATERIAL.							
Apple pomace,	7	76.7	0.5	1.4	3.9	16.2	1.3
Brewers' grains—dried‡,	15	8.3	4.0	21.3	13.2	47.3	5.9
Brewers' grains—wet,	15	75.7	1.0	5.4	3.8	12.5	1.6
Corn cobs,	18	10.7	1.4	2.4	30.1	54.9	0.5
Cotton-seed hulls,	4	10.4	2.6	4.0	44.4	36.6	2.0
Cotton-seed meal,	35	8.2	7.2	42.3	5.6	23.6	13.1
Gluten feed ||,	46	8.2	1.0	22.8	7.0	50.3	10.7
"Chicago" gluten meal ||,	17	9.6	1.1	32.6	1.1	48.4	7.2
"Cream" gluten meal ||,	10	7.8	1.6	37.1	1.6	34.6	17.3
Hominy chop,	....	11.1	2.5	9.8	3.8	64.5	7.4
Linseed meal—new process,	14	10.1	5.8	33.2	9.5	38.4	3.0
Linseed meal—old process,	21	9.2	5.7	32.9	8.9	35.4	7.9
Malt sprouts,	4	10.2	5.7	23.2	10.7	48.5	1.7

TABLE II—Continued.

	Number of analyses.	Percentage Composition.					
		Water.	Ash.	Protein.	Crude fibre.	Nitrogen-free extract.	Fat.
DAIRY PRODUCTS.							
Buttermilk,	24	91.8	0.8	2.8	....	4.3	0.3
Milk,	....	87.3	0.7	3.1	....	5.1	3.8
Skim milk,	303	90.5	0.8	3.5	....	4.8	0.4
Whey,	....	93.0	0.8	0.8	....	5.0	0.4

*Partial compilation by the writer.
†The stalks and leaves of corn after the removal of the ears.
‡Average of J. & W.'s figures and analyses by New Jersey and Pennsylvania Stations.
|| Report New Jersey Experiment Station, 1894.

TABLE III.

DIGESTIBLE MATTER IN FEEDING-STUFFS.

The Average American digestion co-efficients compiled by Jordan (Expt. St. Record VI. 5) have been used so far as possible. When American co-efficients were not available, Wolff's German co-efficients (Mentzel & v. Lengerke, 1895) has been employed. In those cases in which the digestibility had to be estimated from that of other similar feeding-stuffs the figures are put in parentheses.

	Number of analyses.	Total dry matter.	Per cent. of digestible matter.			Nutritive ratio.
			Protein.	Carbhydrates and fat.*	Total.	
SOILING FODDER.						
Corn—dent, cut before glazing,	54	20.3	1.1	12.7	13.8	1:11.5
Cow pea,	10	16.4	1.6	7.5	9.1	1: 4.7
Oats,	5	37.8	(2.7)	(24.6)	(27.3)	(1: 9.1)
Red clover,	43	29.2	3.0	14.9	17.9	1: 5.0
Rye,	6	18.0	1.9	10.9	12.8	1: 5.7
Soja bean,	6	25.2	(2.3)	(11.6)	(13.9)	(1: 5.0)
SILAGE.						
Corn silage—kernels glazing or more mature,	14	27.9	1.1	18.2	19.3	1:16.5
Red clover,	5	28.0	(2.8)	(15.3)	(18.1)	(1: 5.5)
HAY, STRAW, ETC.						
Alfalfa hay,	21	91.6	10.4	43.0	53.4	1: 4.1
Corn forage—field cured,	35	57.8	2.5	36.1	38.6	1:14.4
Corn stover—field cured,	60	59.9	2.0	34.8	36.8	1:17.4
Clover hay—red,	38	84.7	6.4	38.5	44.9	1: 6.0
Millet hay,	12	92.3	4.5	54.7	59.2	1:12.2
Mixed hay,	....	85.7	4.7	42.7	47.4	1: 9.1
Oat straw,	12	90.8	1.4	45.9	47.3	1:32.8
Orchard-grass hay,	10	90.1	4.8	45.2	50.0	1: 9.4
Red top hay,	9	91.1	4.8	49.2	54.0	1:10.3
Rye straw,	7	92.9	0.6	42.5	43.1	1:69.2
Timothy hay,	68	86.8	2.9	46.9	49.8	1:16.2
Wheat straw,	7	90.4	0.6	39.3	39.9	1:65.5
ROOTS AND TUBERS.						
Carrots,	8	11.4	(0.9)	(8.9)	(9.8)	(1: 9.9)
Mangel wurzels,	9	9.1	1.1	5.4	6.5	1: 4.9
Potatoes,	12	21.1	0.9	15.7	16.6	1:17.4
Rutabagas,	4	11.4	1.0	8.5	9.5	1: 8.5
Sugar beets,	19	13.5	1.6	10.9	12.5	1: 6.8
Turnips,	8	9.5	1.0	7.7	8.7	1: 7.7
GRAIN.						
Barley,	10	89.1	8.7	69.2	77.9	1: 8.0
Buckwheat,	8	87.4	(7.8)	(54.8)	(62.6)	(1: 7.0)
Corn—dent,	86	89.4	6.2	75.2	81.4	1:12.1
Corn—flint,	68	88.7	6.3	74.9	81.2	1:11.9
Corn—sweet,	26	91.2	7.0	78.4	85.4	1:11.2
Oats,	30	89.0	9.2	53.2	62.4	1: 5.8
Peas,	....	85.6	18.8	53.5	72.3	1: 2.8
Rye,	6	88.4	(6.4)	(70.3)	(76.7)	(1:11.0)
Sorghum seed,	10	87.8	(5.4)	(66.8)	(72.2)	(1:12.3)
Wheat—spring,	13	89.6	(7.5)	(70.0)	(77.5)	(1: 9.3)
Wheat—winter,	262	89.5	(7.1)	(70.5)	(77.6)	(1: 9.9)
Wheat—winter, raised in Pennsylvania,	41	89.3	(7.1)	(70.5)	(77.6)	(1: 9.9)
MILL PRODUCTS.						
Barley meal,	3	88.1	7.4	68.8	76.2	1: 9.3
Buckwheat middlings,	3	86.8	(23.7)	(50.5)	(74.2)	(1: 2.1)
Corn meal,	77	85.0	5.5	71.1	76.6	1:12.9
Corn-and-cob meal,	7	84.9	4.4	66.5	70.9	1:15.1
Pea meal,	2	89.5	16.8	53.1	69.9	1: 3.2
Rye bran,	7	88.4	(11.5)	(48.8)	(60.3)	(1: 4.2)
Wheat bran,	88	88.1	12.0	45.4	57.4	1: 3.8
Wheat middlings,	32	87.9	12.8	60.9	73.7	1: 4.8
Wheat shorts,	12	89.2	12.2	58.6	70.8	1: 4.8
BYE-PRODUCTS AND WASTE MATERIAL.						
Apple pomace,	7	23.3	(1.1)	(16.4)	(17.5)	(1:14.9)
Brewers' grains—dried,	15	91.7	16.8	47.1	63.9	1: 2.8
Brewers' grains—wet,	15	24.3	4.3	12.8	17.1	1: 3.0
Corn cobs,	18	89.3	0.4	53.2	53.6	1:33.0
Cotton-seed hulls,	4	89.6	0.4	34.9	35.3	1:87.3
Cotton-seed meal,	35	91.8	37.2	43.7	80.9	1: 1.2
Gluten feed,	46	91.7	19.4	63.3	82.7	1: 3.3
"Chicago" gluten meal,	17	90.4	27.7	56.9	84.6	1: 2.1
"Cream" gluten meal,	10	92.2	32.3	72.5	104.8	1: 2.2
Hominy chop,	....	88.9	(7.1)	(79.5)	(86.6)	1:11.2

TABLE III—Continued.

	Number of analyses.	Total dry matter.	Per cent. of digestible matter.			Nutritive ratio.
			Protein.	Carbhydrates and fat.*	Total.	
Linseed meal—new process, ...	14	89.9	28.9	44.9	73.8	1: 1.6
Linseed meal—old process, ...	21	90.8	29.3	48.5	77.8	1: 1.7
Malt sprouts, ...	4	89.8	18.6	40.3	58.9	1: 2.2
DAIRY PRODUCTS.						
Butermilk, ...	24	8.2	2.8	5.0	7.8	1: 1.8
Milk, ...	....	12.7	3.1	13.7	16.8	1: 4.4
Skim milk, ...	303	9.5	3.5	5.7	9.2	1: 1.6
Whey, ...	....	7.0	0.8	5.9	6.7	1: 7.4

*The fat reduced to its starch equivalent by multiplying by 2.25.

TABLE IV.

FEEDING STANDARDS.

A—Per day and one thousand pounds live weight.*

	Dry matter.	Digestible.			Nutritive ratio.
		Protein.	Carbhydrates and fat.	Total.	
	Lbs.	Lbs.	Lbs.	Lbs.	
Oxen at rest in stall,	17.5	0.7	8.3	9.0	1:11.9
Wool sheep, coarser breeds,	20.0	1.2	10.8	12.0	1: 9.0
Wool sheep, finer breeds,	22.5	1.5	12.0	13.5	1: 8.0
Oxen moderately worked,	24.0	1.6	12.0	13.6	1: 7.5
Oxen heavily worked,	26.0	2.4	14.3	16.7	1: 6.0
Horses lightly worked,	20.0	1.5	10.4	11.9	1: 6.9
Horses moderately worked,	21.0	1.7	11.8	13.5	1: 6.9
Horses heavily worked,	23.0	2.3	14.3	16.6	1: 6.2
Milk cows, Wolff's standard,	24.0	2.5	13.4	15.9	1: 5.4
Milk cows, Wisconsin standard,	24.5	2.2	14.9	17.1	1: 6.8
Fattening oxen, preliminary period,	27.0	2.5	16.1	18.6	1: 6.4
Fattening oxen, main period,	26.0	3.0	16.4	19.4	1: 5.5
Fattening oxen, finishing period,	25.0	2.7	16.2	18.9	1: 6.0
Fattening sheep, preliminary period,	26.0	3.0	16.3	19.3	1: 5.4
Fattening sheep, main period,	25.0	3.5	15.8	19.3	1: 4.5
Fattening swine, preliminary period,	36.0	5.0	27.5	32.5	1: 5.5
Fattening swine, main period,	31.0	4.0	24.0	28.0	1: 6.0
Fattening swine, finishing period,	23.5	2.7	17.5	20.2	1: 6.5
Growing cattle:					
Age. Months. / Average live weight per head.					
2—3 / 150 lbs.,	22.0	4.0	18.3	22.3	1: 4.6
3—6 / 300 lbs.,	23.4	3.2	15.8	19.0	1: 4.9
6—12 / 500 lbs.,	24.0	2.5	14.9	17.4	1: 6.0
12—18 / 700 lbs.,	24.0	2.0	13.9	15.9	1: 7.0
18—24 / 850 lbs.,	24.0	1.6	12.7	14.3	1: 8.0
Growing sheep:					
5—6 / 56 lbs.,	28.0	3.2	17.4	20.6	1: 5.4
6—8 / 67 lbs.,	25.0	2.7	14.7	17.4	1: 5.4
8—11 / 75 lbs.,	23.0	2.1	12.5	14.6	1: 6.0
11—15 / 82 lbs.,	22.5	1.7	11.8	13.5	1: 7.0
15—20 / 85 lbs.,	22.0	1.4	11.1	12.5	1: 8.0

*The fattening rations are calculated for one thousand pounds live weight at the beginning of the fattening.

TABLE IV—Continued.

B—Per day and head.

		Dry matter.	Digestible.			Nutritive ratio.
			Protein.	Carbhy-drates and fat.	Total.	
		Lbs.	Lbs.	Lbs.	Lbs.	
Growing fat pigs:						
Age. Months.	Average live weight per head.					
2—3	50 lbs.,	42.0	7.5	30.0	37.5	1:4.0
3—5	100 lbs.,	34.0	5.0	25.0	30.0	1:5.0
5—6	125 lbs.,	31.5	4.3	23.7	28.0	1:5.5
6—8	170 lbs.,	27.0	3.4	20.4	23.8	1:6.0
8—12	250 lbs.,	21.0	2.5	16.2	18.7	1:6.5
Growing cattle:						
2—3	150 lbs.,	3.3	0.6	2.8	3.4	1:4.6
3—6	300 lbs.,	7.0	1.0	4.9	5.9	1:4.9
6—12	500 lbs.,	12.0	1.3	7.5	8.8	1:6.0
12—18	700 lbs.,	16.8	1.4	9.7	11.1	1:7.0
18—24	850 lbs.,	20.4	1.4	11.1	12.5	1:8.0
Growing sheep:						
5—6	56 lbs.,	1.6	0.18	0.974	1.154	1:5.4
6—8	67 lbs.,	1.7	0.18	0.981	1.161	1:5.4
8—11	75 lbs.,	1.7	0.16	0.953	1.113	1:6.0
11—15	82 lbs.,	1.8	0.14	0.975	1.115	1:7.0
15—20	85 lbs.,	1.9	0.12	0.955	1.075	1:8.0
Growing fat swine:						
2—3	50 lbs.,	2.1	0.38	1.50	1.88	1:4.0
3—5	100 lbs.,	3.4	0.50	2.50	3.00	1:5.0
5—6	125 lbs.,	3.9	0.54	2.96	3.50	1:5.5
6—8	170 lbs.,	4.6	0.58	3.47	4.05	1:6.0
6—12	250 lbs.,	5.2	0.62	4.05	4.67	1:6.5

TABLE V.

FERTILIZING CONSTITUENTS OF AMERICAN FEEDING-STUFFS AND MANURIAL VALUE PER TON.

From the Handbook of Experiment Station Work, except as otherwise noted, nitrogen valued at 12 cents per pound, phosphoric acid at 4 cents and potash at 5 cents.

	Pounds in 100 pounds.			Value in dollars per ton.			
	Nitrogen.	Phosphoric acid	Potash.	Nitrogen.	Phosphoric acid.	Potash.	Total.
SOILING FODDER.							
Corn—dent, cut before glazing,	0.41	0.15	0.33	.984	.120	.33	1.43
Cow pea,	0.27	0.10	0.31	.648	.080	.31	1.04
Crimson clover (just heading)*,	0.40	0.12	0.34	.960	.096	.34	1.40
Crimson clover (full bloom)*,	0.51	0.12	0.35	1.224	.096	.35	1.67
Orchard grass (in bloom),	0.43	0.16	0.76	1.032	.128	.76	1.92
Pasture grass,*	0.75	0.19	0.60	1	.152	.60	2.55
Red clover,	0.53	0.13	0.46	1.272	.104	.46	1.84
Rye,	0.33	0.15	0.73	.792	.120	.73	.64
Soja bean,	0.29	0.15	0.53	.696	.120	.53	1.35
SILAGE.							
Corn silage—average of all analyses, ¶	0.28	0.11	0.37	.672	.088	.37	1.13
Red clover,	0.53	0.13	0.46	1.272	.104	.46	1.84
HAY, STRAW, ETC.							
Alfalfa hay,	2.19	0.51	1.68	5.256	.408	1.68	7.34
Corn forage—field cured,	1.76	0.54	0.89	4.225	.432	.89	5.55
Corn stover—field cured,	1.04	0.29	1.40	2.496	.232	1.40	4.13
Clover hay—red,	2.07	0.38	2.20	4.968	.304	2.20	7.47
Millet hay,	1.20	0.35	1.30	2.880	.280	1.30	4.46
Mixed meadow-grass hay,*	1.02	0.26	1.48	2.448	.208	1.48	4.14
Mixed hay,	1.67	0.46	1.55	4.009	.368	1.55	5.93
Oat straw,	0.62	0.20	1.24	1.488	.160	1.24	2.89
Orchard-grass hay,	1.31	0.41	1.88	3.144	.328	1.88	5.35
Red-top hay,	0.15	0.36	1.02	2.760	.288	1.02	4.07
Rye straw,	0.46	0.28	0.79	1.104	.224	.79	2.12
Timothy hay,	1.26	0.53	0.90	3.024	.424	.90	4.35
Wheat straw,	0.59	0.12	0.51	1.416	.096	.51	2.02
Wheat chaff,	0.79	0.70	0.42	1.896	.560	.42	2.88
ROOTS AND TUBERS.							
Carrots,	0.15	0.09	0.51	.360	.072	.51	.94
Mangel wurzels,	0.19	0.09	0.38	.456	.072	.38	.91
Potatoes,	0.21	0.07	0.29	.504	.056	.29	.85
Rutabagas,	0.19	0.12	0.49	.456	.096	.49	1.04
Sugar beets,	0.22	0.10	0.48	.528	.080	.48	1.09
Turnips,	0.18	0.10	0.39	.432	.080	.39	.90
GRAIN.							
Barley,	1.51	0.79	0.48	3.625	.632	.48	4.74
Buckwheat,	1.44	0.44	0.21	3.456	.352	.21	4.02
Corn—dent,*	1.65	0.70	0.40	3.961	.560	.40	4.92
Corn—flint,*	1.68	0.70	0.40	4.033	.560	.40	4.99
Corn—sweet,*	1.82	0.72	0.41	4.369	.576	.41	5.36
Oats,	2.06	0.82	0.62	4.945	.656	.62	6.22
Peas,	3.08	0.82	0.99	7.393	.656	.99	9.04
Rye,	1.76	0.82	0.54	4.225	.656	.54	5.42
Sorghum seed,	1.48	0.81	0.42	3.553	.648	.42	4.62
Wheat—spring,	2.36	0.70	0.39	5.665	.560	.39	6.62
Wheat—winter,	2.36	0.89	0.61	5.665	.712	.61	6.99
MILL PRODUCTS.							
Barley meal,	1.55	0.66	0.34	3.720	.528	.34	4.59
Buckwheat middlings,†	4.62	1.73	1.56	1.109	1.38	1.56	14.03
Corn meal,	1.58	0.63	0.40	3.792	.504	.40	4.70
Corn-and-cob meal,	1.41	0.57	0.47	3.384	.456	.47	4.31
Pea meal,	3.08	0.82	0.99	7.392	.656	.99	9.04
Rye bran,	2.32	2.28	1.40	5.568	1.824	1.40	8.79
Wheat bran,	2.67	2.89	1.61	6.408	2.312	1.61	10.33
Wheat middlings,	2.63	0.95	0.63	6.312	.760	.63	7.70
Wheat shorts,*	2.42	1.38	0.65	5.808	1.104	.65	7.56
BYE PRODUCTS AND WASTE MATERIAL.							
Apple pomace,	0.23	0.02	0.13	.552	.016	.13	.70
Brewers' grains—dried,	3.05	1.26	1.55	7.322	1.008	1.55	9.88
Brewers' grains—wet,	0.89	0.31	0.05	2.136	.248	.05	2.43
Cerealine feed,*	1.69	1.25	0.67	4.056	1.000	.67	5.73
Corn oil meal,*	3.96	1.45	0.17	9.504	1.160	.17	10.83
Corn cobs,	0.50	0.06	0.06	1.200	.048	.60	1.85

*Report New Jersey Experiment Station, 1894.

4--21--97

TABLE V—Continued.

	Pounds in 100 pounds.			Value in dollars per ton.			
	Nitrogen.	Phosphoric acid.	Potash.	Nitrogen.	Phosphoric acid.	Potash.	Total.
Cotton-seed hulls,	0.75	0.18	1.08	1.800	.144	1.08	3.02
Cotton-seed meal,	6.64.	2.68	1.79	15.936	2.144	1.79	19.87
Gluten meal,	5.03	0.33	0.05	12.072	.264	.05	12.39
Gluten feed,	3.44	0.38	0.07	8.256	.304	.07	8.63
Chicago gluten meal,*	5.52	0.29	0.05	13.248	.232	.05	13.53
Grano gluten feed,*	4.96	0.66	0.20	11.904	.528	.20	12.63
Germ meal,	3.48	6.16	2.91	8.352	4.928	2.91	16.19
Linseed meal—new process,	5.78	1.83	1.39	13.872	1.464	1.39	16.73
Linseed meal—old process,	5.43	1.66	1.37	13.032	1.328	1.37	15.73
Malt sprouts,	3.55	1.43	1.63	8.520	1.144	1.63	11.29
DAIRY PRODUCTS.							
Butter,	0.12	0.04	0.04	.288	.032	.04	.36
Buttermilk,	0.48	0.17	0.16	1.152	.136	.16	1.45
Cheese,	3.93	0.60	0.12	9.432	.480	.12	10.03
Cream,	0.40	0.15	0.13	.960	.120	.13	1.21
Milk,	0.53	0.19	0.18	1.272	.152	.18	1.60
Skim milk,	0.56	0.20	0.19	1.344	.160	.19	1.69
Whey,	0.15	0.14	0.18	.360	.112	.18	.65

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*Report New Jersey Experiment Station, 1894.

†The nitrogen from Jenkins & Winton's compilation of analyses of American Feeding Stuffs (O. E. S. Bulletin No. 11). The phosphoric acid and potash computed on the assumption that the total ash has the same composition as that found by v. Wolff (Aschen-Analysen, II 22) for buckwheat bran.

THE COMPARATIVE VALUE OF BUCKWHEAT MIDDLINGS, DRIED BREWERS' GRAINS AND CEREALINE FOR MILK AND BUTTER PRODUCTION.

BY HARRY HAYWARD AND R. J. WELD.

GENERAL CONCLUSIONS.

1. The results of this experiment indicate that, for milk and butter production, dried brewers' grains, buckwheat middlings and cerealine are equally valuable when fed judiciously, as part of a balanced ration.

2. That so far as could be observed, none of these foods produced a detrimental effect upon the flavor or quality of the milk and butter.

3. In view of the results stated, the choice of the above mentioned foods would depend entirely upon their cost delivered at the railroad station.

4. That, with prevailing prices for dairy products and food stuffs, and with good cows, milk and butter can be produced at such a cost as to leave a considerable margin of profit for the dairyman.

DETAILS OF THE EXPERIMENT.

At the present time, dairymen recognize the importance of feeding their cows enough protein to make the proportion of protein to carbohydrates approximately that of 1 :5 to 7. It is necessary usually to purchase this protein in one form or another, since, with the exception of a few crops, this part of a ration cannot be produced to advantage on the farm. This being the case, the question before the dairyman when about to purchase feed with which to balance his coarse feed and corn, is, in what form can this be purchased most cheaply. There are many by-products on the market, all of which contain more or less protein, although differing materially in price. As the chemical analysis of a food does not always show its value for feeding, and as it is important that feeders have an idea of the various by-products which are put on the market, the experiment here described was undertaken, beginning January 26, and closing June 1, 1897.

THE FEEDING-STUFFS.

Buckwheat middlings, which is a by-product in the manufacture of buckwheat flour, is one of the by-products richest in digestible protein, containing nearly twice the amount found in wheat bran. In this test it was readily eaten by the cows and had no bad effect upon the milk and butter. It needs, however, to be watched very carefully, if stored in quantities of much bulk, as it is likely to heat unless mixed with something like wheat middlings. At this writing it can be purchased in car-load lots for $15 per ton f. o. b.

Dried brewers' grains, a by-product of breweries, contains nearly all the protein of the grain used for malting, and is rich in this ingredient. As it is kiln-dried, it can be shipped easily and kept almost indefinitely, and it is fed in considerable quantities where it can be obtained easily. Cattle eat it well, and, when fed in connection with corn meal and linseed meal no harmful effect is noticed upon the milk or butter. It is quoted at present in New York City at $13.75 per ton f. o. b.

Cerealine is a by-product in the manufacture of cerealine flakes, a breakfast food made from corn. It is coarse in appearance, looking as though it were composed of the outer coating of the grain mixed with more or less of the kernel. That used in this experiment was purchased in Baltimore and at present is quoted at $18 per ton f. o. b.

PLAN OF EXPERIMENT.

Previous to the beginning of the experiment there was a preliminary period of five days to accustom the cattle to the feed, during which time a record was kept of the food consumed.

For the first period of forty days, from January 31 to March 12, all were fed the ration which served as a control ration throughout the experiment, and which consisted of 4 pounds of buckwheat middlings, 3 pounds corn meal, 1 pound linseed meal, 8.38 pounds mixed hay, and as much cut corn stover as each cow would eat up reasonably clean.

At the end of the first thirty days of the first period, the twelve cows were divided into four trios as nearly alike as possible in point of milk production and food consumption. Each triplet stood together and the conditions for each of the cows were as nearly alike as it was possible to make them.

During the second period, consisting of 40 days, from March 12 to April 21, number one of each triplet received the ration fed to all during period I. Number 2 received the same, excepting that four pounds of dried brewers' grains were substituted for the buckwheat middlings. Number 3 also received the same, excepting that four pounds of cerealine were substituted for the buckwheat middlings.

During the third period, from April 21 to June 1, all the cattle were fed alike, receiving the same ration as during the first period.

In every case the grain ration was fed dry and by itself the first thing in the morning, and before milking in the evening. During the three periods of 120 days, the health of the cows was excellent, with the exception of the cow Heliotrope, who, at the beginning of the third period was taken off the experiment on account of derangement of her blood. It was not thought, however, that this was in any way due to the food which she ate.

The twelve cows used were separated into four trios, with one cow in each trio acting as control for the other two, in order that the results might be studied, not only as a whole, but so that any marked difference in production during the second period, when the different rations were fed, might be seen in each triplet, thus making the results more conclusive than they would have been had the animals been divided into three lots, and then the lots compared as a whole.

ANIMALS.

The following table contains a brief description of the animals, arranged in trios used for the experiment.

	Name of Cow.	Breed.	Age.	No. of days fresh at the beginning of the experiment.
Trio 1.	Iona,	Seventh-eighths Guernsey,	5	75
	Catherine,	Three-fourths Guernsey,	3	30
	Deputy's Floret,	Registered Guernsey,	2	10
Trio 2.	Lucy,	Jersey-Guernsey,	10	71
	Ramora,	One-half Guernsey,	3	17
	Purdy,	Jersey,	3	33
Trio 3.	Sappho,	One-half Guernsey,	3	33
	Primrose,	Three-fourths Guernsey,	8	70
	Lilac,	Seven-eighths Guernsey,	6	6
Trio 4.	Victoria,	One-half Guernsey,	3	85
	Lilly,	Three-fourths Guernsey,	3	22

SAMPLING.

The coarse fodders in this experiment were weighed up in sacks every five days and placed in bins in front of the cows, and a definite amount fed each day. In the case of the corn stover, a sample was drawn at each weighing up for the determination of loss in air-drying. Similar samples were taken of any of the stover that was refused. From all the samples taken during this experiment a composite sample was drawn for a complete analysis upon which the computation of the amount of total digestible matter is based. Toward the latter end of each period samples of hay were drawn for loss upon air-drying and these too were combined and a sample drawn for complete analysis.

The grain ration for the first and last period being identical, samples of the grain were drawn in these periods for loss upon air-drying alone, while in the second period, when the different rations were fed, samples of each of the different food stuffs used were taken for complete analysis, upon which the computation of the total amount of digestible matter is based.

RATIONS.

The rations actually eaten during the three periods were as follows:

Summary of Rations eaten per Day and Head.

		Hay. (Lbs.)	Corn stover. (Lbs.)	Corn meal. (Lbs.)	Linseed meal. (Lbs.)	Buckwheat middlings. (Lbs.)	Dried brewers' grains. (Lbs.)	Cerealine. (Lbs.)
	Period I.							
Trio 1.	Iona,	8.38	6.65	3	1	4		
	Catherine,	8.38	4.63	3	1	4		
	Deputy's Floret,	8.38	2.97	3	1	4		
Trio 2.	Lucy,	8.38	6.56	3	1	4		
	Ramona,	8.38	6.33	3	1	4		
	Purdy,	8.38	7.53	3	1	4		
Trio 3.	Sappho,	8.38	5.29	3	1	4		
	Primrose,	8.38	6.49	3	1	4		
	Lilac,	8.38	4.70	3	1	4		
Trio 4.	Victoria,	8.38	5.52	3	1	4		
	Lilly,	8.38	5.05	3	1	4		
	Period II.							
Trio 1.	Iona,	9	6.53	3	1	4		
	Catherine,	9	3.93	3	1		4	
	Deputy's Floret,	9	3.28	3	1			4
Trio 2.	Lucy,	9	6.95	3	1	4		
	Ramona,	9	5.95	3	1		4	
	Purdy,	9	6.01	3	1			4
Trio 3.	Sappho,	9	5.05	3	1	4		
	Primrose,	9	5.52	3	1		4	
	Lilac,	9	4.85	3	1			4
Trio 4.	Victoria,	9	6.09	3	1	4		
	Lilly,	9	5.27	3	1			4
	Period III.							
Trio 1.	Iona,	9	6.00	3	1	4		
	Catherine,	9	3.93	3	1	4		
	Deputy's Floret,	9	3.51	3	1	4		
Trio 2.	Lucy,	9	7.63	3	1	4		
	Ramona,	9	4.96	3	1	4		
	Purdy,	9	5.12	3	1	4		
Trio 3.	Sappho,	9	4.18	3	1	4		
	Primrose,	9	4.72	3	1	4		
	Lilac,	9	4.39	3	1	4		
Trio 4.	Victoria,	9	5.45	3	1	4		
	Lilly,	9	5.22	3	1	4		

It will be seen at a glance that the amount of food eaten by the cows was the same in periods I and III, excepting the amount of corn stover, and in period II the only variation was the substitution of the brewers' grains and the cerealine, with the difference in the amount of corn stover noted.

If we consider numbers one of each trio, numbers two of each trio and numbers three of each trio respectively as one lot, it will be seen how the different lots compare in the average amount of food eaten during each period.

Summary of Rations eaten by Each Lot per Day and Head.

		Hay. (Lbs.)	Corn stover. (Lbs.)	Corn meal. (Lbs.)	Linseed meal. (Lbs.)	Buckwheat middlings. (Lbs.)	Dried brewers' grains. (Lbs.)	Cerealine. (Lbs.)
	Period I.							
Lot 1.	Iona,	8.33	6.65	3	1	4	....	....
	Lucy,	8.33	6.56	3	1	4	....	....
	Sappho,	8.33	5.29	3	1	4	....	....
	Victoria,	8.33	5.52	3	1	4	....	....
	Average,	8.33	6.00	3	1	4	....	....
Lot 2.	Catherine,	8.33	4.63	3	1	4	....	....
	Ramona,	8.33	6.33	3	1	4	....	....
	Primrose,	8.33	6.49	3	1	4	....	....
	Average,	8.33	5.82	3	1	4	....	....
Lot 3.	Deputy's Floret,	8.33	2.97	3	1	4	....	....
	Purdy,	8.33	7.53	3	1	4	....	....
	Lilac,	8.33	4.70	3	1	4	....	....
	Lilly,	8.33	5.05	3	1	4	....	....
	Average,	8.33	5.06	3	1	4	....	....
	Period II.							
Lot 1.	Iona,	9	6.53	3	1	4	....	....
	Lucy,	9	6.95	3	1	4	....	....
	Sappho,	9	5.05	3	1	4	....	....
	Victoria,	9	6.09	3	1	4	....	....
	Average,	9	6.16	3	1	4	....	....
Lot 2.	Catherine,	9	3.93	3	1	....	4	....
	Ramona,	9	5.95	3	1	....	4	....
	Primrose,	9	5.52	3	1	....	4	....
	Average,	9	5.13	3	1	....	4	....
Lot 3.	Deputy's Floret,	9	3.28	3	1	....	....	4
	Purdy,	9	6.01	3	1	....	....	4
	Lilac,	9	4.85	3	1	....	....	4
	Lilly,	9	4.85	3	1	....	....	4
	Average,	9	4.75	3	1	....	....	4
	Period III.							
Lot 1.	Iona,	9	6.00	3	1	4	....	....
	Lucy,	9	7.63	3	1	4	....	....
	Sappho,	9	4.18	3	1	4	....	....
	Victoria,	9	5.45	3	1	4	....	....
	Average,	9	5.82	3	1	4	....	....
Lot 2.	Catherine,	9	3.93	3	1	4	....	....
	Ramona,	9	4.96	3	1	4	....	....
	Primrose,	9	4.76	3	1	4	....	....
	Average,	9	4.40	3	1	4	....	....
Lot 3.	Deputy's Floret,	9	3.51	3	1	4	....	....
	Purdy,	9	5.12	3	1	4	....	....
	Lilac,	9	4.39	3	1	4	....	....
	Lilly,	9	5.22	3	1	4	....	....
	Average,	9	4.56	3	1	4	....	....

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Averages.

	Hay. (Lbs.)	Corn stover. (Lbs.)	Corn meal. (Lbs.)	Linseed meal. (Lbs.)	Buck-wheat middlings. (Lbs.)	Brewers' Grains. (Lbs.)	Cerealine. (Lbs.)
Period I.							
Lot 1,	8.38	6.00	3	1	4	....	....
Lot 2,	8.38	5.82	3	1	4	....	....
Lot 3,	8.38	5.06	3	1	4	....	....
Period II.							
Lot 1,	9	6.16	3	1	4	....	....
Lot 2,	9	5.13	3	1	....	4	....
Lot 3,	9	4.75	3	1	....	....	4
Period III.							
Lot 1,	9	5.82	3	1	4	....	....
Lot 2,	9	4.40	3	1	4	....	....
Lot 3,	9	4.56	3	1	4	....	....

In the amount of food eaten by each lot during the three periods, the only difference is in the amount of corn stover consumed, and even in this the ratio of the amount eaten by lots two and three to the amount eaten by lot one is about the same during the three periods.

The following table gives the computed digestible matter eaten by each cow during the three periods. The digestibility of the foods used in this experiment is assumed to be the same as the average of a number of results of digestion trials compiled by Jordan,* with the exception of buckwheat middlings and cerealine, the digestion co-efficients of which were estimated from other similar feeding stuffs whose digestibility was known.

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* Experiment Station Record, VI, 5.

Computed Digestible Matter of Rations per Day and Head.

		Total dry matter. (Lbs.)	Digestible			Nutritive ratio.
			Protein. (Lbs.)	Carbohydrates and fat. (Lbs.)	Total. (Lbs.)	
	Period I.					
Trio 1.	Iona,	19.73	2.19	9.54	11.73	1:4.3
	Catherine,	18.17	2.13	8.99	11.14	1:4.2
	Deputy's Floret,	16.78	2.11	8.50	10.61	1:4.0
Trio 2.	Lucy,	19.64	2.19	9.51	11.70	1:4.3
	Ramona,	19.49	2.18	9.46	11.64	1:4.3
	Purdy,	20.42	2.21	9.78	11.99	1:4.4
Trio 3.	Sappho,	18.68	2.16	9.17	11.33	1:4.2
	Primrose,	19.63	2.19	9.50	11.69	1:4.4
	Lilac,	18.20	2.15	9.09	11.15	1:4.2
Trio 4.	Victoria,	18.86	2.17	9.24	11.41	1:4.3
	....	....	....	....	....	....
	Lilly,	18.50	2.16	9.11	11.27	1:4.2
	Period II.					
Trio 1.	Iona,	20.35	2.13	9.70	11.83	1:4.6
	Catherine,	18.75	2.02	8.09	10.11	1:4.0
	Deputy's Floret,	17.69	1.62	8.95	10.57	1:5.5
Trio 2.	Lucy,	20.64	2.14	9.80	11.94	1:4.6
	Ramona,	19.93	2.06	8.51	10.56	1:4.1
	Purdy,	20.01	1.69	9.72	11.41	1:5.7
Trio 3.	Sappho,	19.20	2.09	9.30	11.39	1:4.4
	Primrose,	19.90	2.05	8.50	10.55	1:4.2
	Lilac,	19.06	1.66	9.39	11.05	1:5.7
Trio 4.	Victoria,	20.04	2.12	9.59	11.71	1:4.5
	....	....	....	....	....	....
	Lilly,	19.40	1.67	9.51	11.18	1:5.7
	Period III.					
Trio 1.	Iona,	20.40	2.25	9.59	11.84	1:4.2
	Catherine,	18.65	2.20	8.97	11.17	1:4.1
	Deputy's Floret,	18.24	2.19	8.83	11.02	1:4.0
Trio 2.	Lucy,	21.66	2.29	10.02	12.31	1:4.4
	Ramona,	19.48	2.23	9.27	11.50	1:4.1
	Purdy,	19.71	2.23	9.35	11.58	1:4.2
Trio 3.	Sappho,	18.86	2.21	9.05	11.26	1:4.1
	Primrose,	19.34	2.22	9.22	11.44	1:4.1
	Lilac,	19.06	2.21	9.12	11.33	1:4.1
Trio 4.	Victoria,	19.95	2.24	9.36	11.60	1:4.2
	....	....	....	....	....	....
	Lilly,	19.71	2.23	9.35	11.58	1:4.2

In comparing these figures it will be noticed that in the first and third periods the total digestible nutrients consumed by the individuals of each trio is quite uniformly alike. In period two, however, when the different rations were fed, there is quite a marked difference in the total amount of digestible matter consumed, owing partially to the lack of digestible carbohydrates in the dried brewers' grains and partially to the fact that, with a single exception, the cows fed on brewer's grains ate less corn stover during this period.

It may be noticed in passing that, although in every case in the second period where the dried brewers' grains were fed, there is a lack of total digestible matter as compared with the total digestible matter consumed by the other two of each trio, for some reason, these cows did not seem to make up the difference by eating more corn stover although they were fed all they would eat. Again, it will be noticed that number three of each trio receiving the cerealine ate a wider ration than the other two cows of each trio, owing to a lack of protein in the cerealine compared with the other feeds.

Comparing the three rations by lots as above a more comprehensive idea may be had of them:

Average Digestible Matter of Daily Rations.

		Total dry matter (Lbs.)	Digestible		Total. (Lbs.)	Nutritive ratio.
			Protein. (Lbs.)	Carbohydrates and fat. (Lbs.)		
Period I.						
Lot 1.	Iona,	19.73	2.19	9.54	11.73	1:4.3
	Lucy,	19.64	2.19	9.51	11.70	1:4.3
	Sappho,	18.68	2.16	9.17	11.33	1:4.2
	Victoria,	18.86	2.17	9.24	11.41	1:4.3
	Average,	19.23	2.18	9.37	11.57	1:4.29
Lot 2.	Catherine,	18.17	2.15	8.99	11.14	1:4.2
	Ramona,	19.49	2.18	9.46	11.64	1:4.3
	Primrose,	19.63	2.19	9.50	11.33	1:4.2
	Average,	19.10	2.17	9.32	11.37	1:4.29
Lot 3.	Deputy's Floret,	16.78	2.11	8.50	10.61	1:4.0
	Purdy,	20.43	2.21	9.78	11.99	1:4.4
	Lilac,	18.20	2.15	9.00	11.15	1:4.2
	Lilly,	18.50	2.16	9.11	11.27	1:4.2
	Average,	18.48	2.16	9.10	11.26	1:4.21
Period II.						
Lot 1.	Iona,	20.35	2.13	9.70	11.83	1:4.6
	Lucy,	20.64	2.14	9.80	11.94	1:4.6
	Sappho,	19.20	2.09	9.30	11.39	1:4.4
	Victoria,	20.04	2.12	9.59	11.71	1:4.5
	Average,	20.06	2.12	9.60	11.72	1:4.53
Lot 2.	Catherine,	18.75	2.02	8.09	10.11	1:4.0
	Ramona,	19.93	2.05	8.51	10.56	1:4.1
	Primrose,	19.90	2.05	8.50	10.55	1:4.2
	Average,	19.53	2.04	8.37	10.41	1:4.20
Lot 3.	Deputy's Floret,	17.69	1.62	8.95	10.57	1:5.5
	Purdy,	20.01	1.69	9.72	11.41	1:5.7
	Lilac,	19.06	1.66	9.39	11.05	1:5.7
	Lilly,	19.40	1.67	9.51	11.18	1:5.7
	Average,	19.04	1.66	9.39	11.05	1:5.66
Period III.						
Lot 1.	Iona,	20.40	2.25	9.59	11.84	1:4.2
	Lucy,	21.66	2.29	10.02	12.31	1:4.4
	Sappho,	18.86	2.21	9.05	11.26	1:4.1
	Victoria,	19.95	2.24	9.36	11.60	1:4.2
	Average,	20.22	2.25	9.51	11.75	1:4.22
Lot 2.	Catherine,	18.65	2.20	8.97	11.17	1:4.1
	Ramona,	19.48	2.23	9.27	11.50	1:4.1
	Primrose,	19.34	2.22	9.22	11.44	1:4.1
	Average,	19.16	2.22	9.15	11.37	1:4.1
Lot 3.	Deputy's Floret,	18.24	2.19	8.83	11.02	1:4.0
	Purdy,	19.71	2.23	9.35	11.58	1:4.2
	Lilac,	19.06	2.21	9.12	11.33	1:4.1
	Lilly,	19.71	2.23	9.35	11.58	1:4.2
	Average,	19.18	2.22	9.16	11.38	1:4.14

Averages Compared.

	Total dry matter. (Lbs.)	Digestible		Total digestible matter. (Lbs.)	Nutritive ratio.
		Protein. (Lbs.)	Carbohydrates and fat. (Lbs.)		
Period I.					
Lot 1,	19.23	2.18	9.37	11.57	1:4.29
Lot 2,	19.10	2.17	9.32	11.37	1:4.29
Lot 3,	18.48	2.16	9.10	11.26	1:4.21
Period II.					
Lot 1,	20.06	2.12	9.60	11.72	1:4.53
Lot 2,	19.53	2.04	8.37	10.41	1:4.20
Lot 3,	19.04	1.66	9.39	11.05	1:5.66
Period III.					
Lot 1,	20.22	2.25	9.51	11.75	1:4.22
Lot 2,	19 16	2.22	9.15	11.37	1:4.1
Lot 3,	19.18	2.22	9.16	11.38	1:4.14

YIELD OF MILK.

The average daily yield of milk, of solids-not-fat and of fat by each cow is shown in the following tables, the results being arranged first by periods and second by lots.

Yields per Day.

		Milk. (Lbs.)	Solids not fat. (Lbs.)	Fat. (Lbs.)
	Period I.			
Trio 1.	Iona,	18.806	1.724	.906
	Catherine,	18.920	1.672	.907
	Deputy's Floret,	19.081	1.788	.897
Trio 2.	Lucy,	24.108	2.224	1.185
	Ramona,	23.054	1.981	.938
	Purdy,	21.937	2.014	1.080
Trio 3.	Sappho,	18.112	1.698	.851
	Primrose,	20.620	1.886	1.030
	Lilac,	22.531	2.081	1.053
Trio 4.	Victoria,	14.347	1.342	.683
	....	....	....	....
	Lilly,	16.560	1.573	.846
	Period II.			
Trio 1.	Iona,	17.223	1.520	.908
	Catherine,	17.361	1.484	.783
	Deputy's Floret,	16.316	1.467	.739
Trio 2.	Lucy,	20.165	1.825	.908
	Ramona,	22.073	1.860	.856
	Purdy,	20.70	1.855	.954
Trio 3.	Sappho,	16.411	1.571	.740
	Primrose,	20.265	1.768	.926
	Lilac,	20.868	1.868	.877
Trio 4.	Victoria,	13.917	1.279	.666
	....	....	....	....
	Lilly,	13.411	1.252	.649
	Period III.			
Trio 1.	Iona,	15.590	1.394	.855
	Catherine,	16.433	1.413	.782
	Deputy's Floret,	14.811	1.338	.758
Trio 2.	Lucy,	17.023	1.578	.903
	Ramona,	20.142	1.699	.827
	Purdy,	18.875	1.673	.928
Trio 3.	Sappho,	15.530	1.402	.693
	Primrose,	18.325	1.588	.866
	Lilac,	20.507	1.820	.943
Trio 4.	Victoria,	14.020	1.249	.640
	....	....	....	....
	Lilly,	12.130	1.090	.630

By comparing the yield of solids-not-fat, and fat by trios for the three periods it will be seen that there is scarcely any appreciable difference. Whatever difference exists in any case is so small that, taking into account the individuality of the cows, it will be impossible to say that any one of the three rations fed is a better milk and butter producer than the other. It may be well to note the yield by lots, as then any difference appearing between the three rations would be emphasized more than by comparing the trios only.

Average Daily Yield per Head by Lots.

Period I.

	Milk (Lbs.)	Solids not fat. (Lbs.)	Fat. (Lbs.)
Lot I.			
Iona,	18.805	1.724	.986
Lucy,	24.103	2.234	1.185
Sappho,	18.112	1.688	.851
Victoria,	14.347	1.342	.683
Average,	18.842	1.747	.926
Lot II.			
Catherine,	18.920	1.672	.907
Ramona,	23.054	1.981	.968
Primrose,	20.620	1.896	1.000
Average,	20.865	1.850	.958
Lot III.			
Deputy's Floret,	19.081	1.788	.897
Purdy,	21.937	2.014	1.080
Lilac,	22.531	2.081	1.053
Lilly,	16.560	1.573	.846
Average,	20.027	1.864	.969

Period II.

	Milk. (Lbs.)	Solids not fat. (Lbs.)	Fat. (Lbs.)
Lot I.			
Iona,	17.228	1.520	.908
Lucy,	20.165	1.825	.998
Sappho,	16.411	1.571	.740
Victoria,	13.917	1.279	.660
Average,	16.929	1.549	.826
Lot II.			
Catherine,	17.361	1.484	.783
Ramona,	22.073	1.860	.856
Primrose,	20.265	1.768	.925
Average,	19.889	1.704	.855
Lot III.			
Deputy's Floret,	16.316	1.467	.739
Purdy,	20.70	1.855	.954
Lilac,	20.868	1.868	.877
Lilly,	13.411	1.252	.649
Average,	17.824	1.610	.805

Period III.

	Milk. (Lbs.)	Solids not fat. (Lbs.)	Fat. (Lbs.)
Lot I.			
Iona,	15.590	1.394	.855
Lucy,	17.023	1.578	.903
Sappho,	15.530	1.402	.693
Victoria,	14.020	1.249	.640
Average,	15.541	1.406	.773
Lot II.			
Catherine,	16.433	1.418	.782
Ramona,	20.142	1.699	.827
Primrose,	18.325	1.583	.866
Average,	18.300	1.566	.825
Lot III.			
Deputy's Floret,	14.811	1.338	.758
Purdy,	18.876	1.673	.928
Lilac,	20.507	1.820	.943
Lilly,	12.130	1.090	.639
Average,	16.581	1.480	.817

Comparison of Averages.

	Milk. (Lbs.)	Per cent. greater or less than Lot 1.	Solids not fat. (Lbs.)	Per cent. greater or less than Lot 1.	Fat. (Lbs.)	Per cent. greater or less than Lot 1.
Period I.						
Lot 1. Buckwheat middlings,	18.842	....	1.747	....	.926	....
Lot 2. Brewers' grains,	20.865	+10.73	1.850	+5.89	.958	+3.55
Lot 1. Buckwheat middlings,	18.842	....	1.747	....	.926	....
Lot 3. Cerealine,	20.027	+6.29	1.864	+6.69	.969	+4.64
Period II.						
Lot 1. Buckwheat middlings,	16.929	....	1.549	....	.826	....
Lot 2. Brewers' grains,	19.889	+17.48	1.704	+10.00	.855	+3.5
Lot 1. Buckwheat middlings,	16.929	....	1.549	....	.826	....
Lot 3. Cerealine,	17.824	+5.28	1.610	+3.93	.805	−2.54
Period III.						
Lot 1. Buckwheat middlings,	15.541	....	1.406	....	.773	....
Lot 2. Brewers' grains,	18.300	+17.75	1.566	+11.38	.825	+6.73
Lot 1. Buckwheat middlings,	15.541	....	1.406	....	.773	....
Lot 3. Cerealine,	16.581	+6.69	1.408	+.14	.817	+5.96

The results shown in the above table may be still more plainly brought out by comparing the averages of periods 1 and 3 with the results of period 2, as follows:

Excess of Production by Lot II over Lot I.

	Milk. Per cent.	Milk solids. Per cent.	Fat. Per cent.
Average of Periods I and III,	14.24	8.64	5.14
Period II,	17.48	10.00	3.50

Excess of Production by Lot III over Lot I.

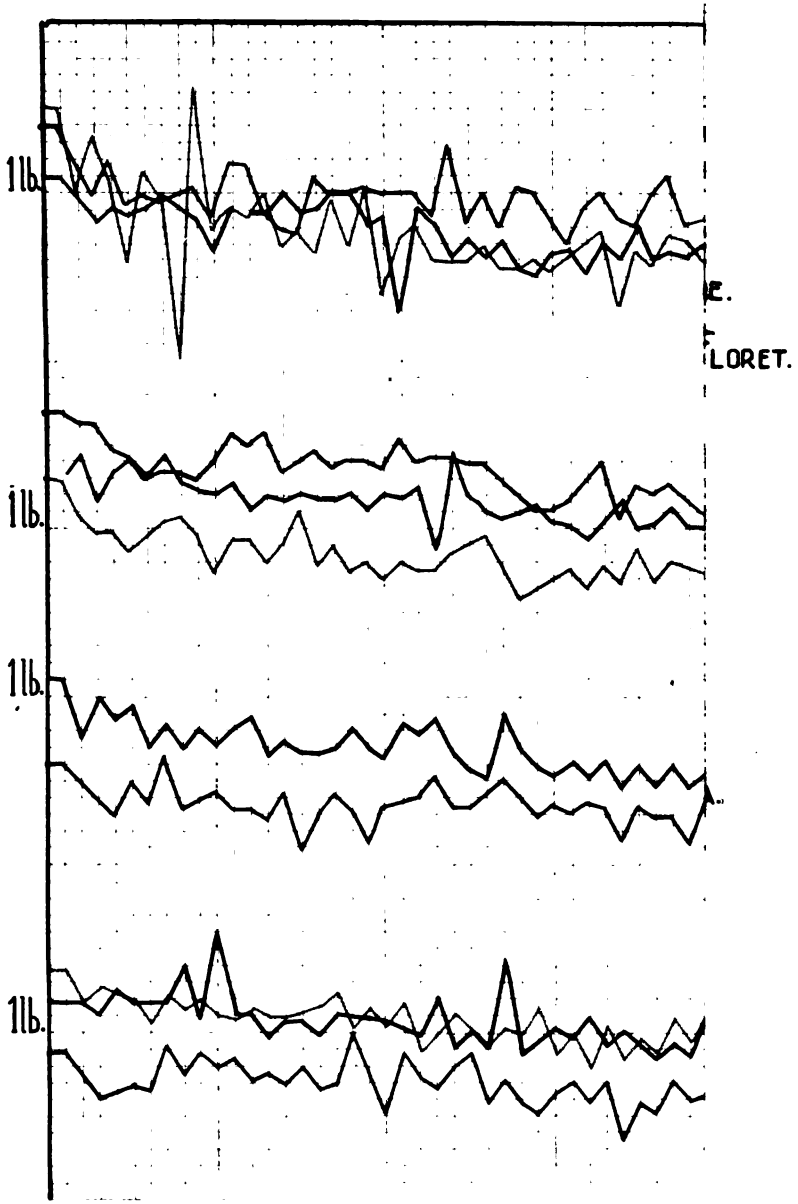
	Milk. Per cent.	Solids not fat. Per cent.	Fat. Per cent.
Average of Periods I and III,	6.49	3.42	5.30
Period II,	5.23	3.93	2.54

It appears from the above figures that both Lots II and III produced more milk than Lot I, when both received the same rations, namely, in periods one and three. It also appears that Lot II in the second period, when it received dried brewers' grains, showed a somewhat greater excess of production over Lot I than in the other two periods, while Lot III in the second period, during which it received cerealine feed, showed a smaller excess of production over Lot I. The differences are small and it seems doubtful whether the variations are greater than might have been expected on a uniform feed. If they have any significance, they would indicate that the dried brewers' grains was slightly superior to an equal weight of buckwheat middlings, while the cerealine feed was slightly inferior to the same weight of buckwheat middlings. According to the estimates of digestible matter contained in previous tables, Lot II received slightly less digestible matter in period two than in periods one and three, but, nevertheless, the production of milk was somewhat greater. It should be noted, however, that the estimated digestibility of the dried brewers' grains is based upon a small number of determinations and it is quite possible that more feed was actually digested from this ration than appears from the computations. In the case of Lot III, there was no material decrease in the estimated amount of total digestible matter, but the nutritive ratio was considerably wider than in periods one and three and this is probably sufficient to account for the slight apparent falling-off in milk production. So far as the main object of the experiment was concerned, namely, the comparison of the actual effect of equal weights of these feeds, the results are not affected by these considerations regarding the probable digestibility of the rations, and plainly show a substantial equality in nutritive effect.

By comparing the averages of the three periods by lots it will be seen that so far as the production of milk, milk solids and milk fat is concerned, the change of ration in the second period made but little, if any, difference. As the following table will show, the gain and loss in live weight of the animals during the time of the experiment was very slight and quite uniform in the different lots. From these results it seems that any choice of the rations fed in these trials would depend entirely upon the cost of each.

DAILY PRODUCTION

PERIOD I – 40 DAYS — CONTROL RATION,



KEY:— BUCKWHEAT

LIVE WEIGHT.

The cows were weighed for five consecutive days at the beginning of each period and for five consecutive days at the end of each period, and the average of these weights was taken to be the weight of the cow at the beginning and end of the period.

Live Weights.

	Weight at beginning of period. (Lbs.)	Weight at end of period. (Lbs.)	Gain or loss expressed in per cent.
Period I.			
Iona,	786	782	— .56
Catherine,	760	757	— .40
Deputy's Floret,	638	631	—1.1
Lucy,	802	796	— .8
Ramona,	880	869	—1.3
Purdy,	714	717	+ .4
Sappho,	763	765	+ .3
Primrose,	927	924	— .3
Lilac,	770	773	+ .4
Victoria,	811	830	+2.3
Period II.			
Iona,	782	807	+3.2
Catherine,	764	788	+3.1
Deputy's Floret,	632	656	+3.8
Lucy,	794	818	+3.0
Ramona,	879	907	+2.2
Purdy,	729	729	0.0
Sappho,	774	788	+1.8
Primrose,	937	951	+1.5
Lilac,	792	798	+ .8
Victoria,	849	851	+ .9
Lilly,	764	783	+2.5
Period III.			
Iona,	800	836	+4.5
Catherine,	767	767	0.0
Deputy's Floret,	631	653	+3.5
Lucy,	805	823	+2.2
Ramona,	886	882	— .4
Purdy,	715	721	+ .8
Sappho,	770	798	+ .4
Primrose,	922	904	— .2
Lilac,	783	764	—2.4
Victoria,	846	861	+2.0
Lilly,	783	789	+ .8

The accompanying diagram represents graphically the amount of fat produced by each cow throughout the experiment. Each small square, considered vertically, represents .05 of a pound of fat, and considered horizontally, represents one day's production. Each set of lines in the diagram represents a trio of cows as they were arranged in the experiment, the green lines representing the production of the cows fed on buckwheat middlings, the red lines the production of those fed on brewers' grains, and the black lines the production of those fed on cerealine.

The periods of forty days each are separated by the heavy perpendicular lines. It will be seen that the production of each trio of cows for each period is quite uniform; in no other way could the equality of results from the different foods used be more clearly seen. In passing, attention may be called to the constant daily variation of production in all the cows, a point which, although not bearing directly upon the experiment, is nevertheless interesting.

COST AND PROFITS.

In estimating the cost of the above foods, the following prices have been assumed:

Mixed hay (per ton),	$10 00
Corn stover (per ton),	4 00
Corn meal (per ton),	15 00
Linseed meal, new process (per ton),	22 00
Buckwheat middlings (per ton),	15 00
Dried brewers' grains (per ton),	13 75
Cerealine (per ton),	18 00

At these prices the cost of the three rations per day was as follows:

Buckwheat middlings (cents),	12
Dried brewers' grains (cents),	11.7
Cerealine (cents),	12.6

Average Cost per Pound for Feed.

	Milk.	Fat.	Butter
Buckwheat middlings,	0.72	14.53	12.45
Brewers' grains,	0.58	13.68	11.72
Cerealine,	0.71	15.65	13.41

This computation presents one important aspect of all feeding problems, namely, the cost of production. It will be readily seen, granting that the manure and skim-milk will pay for the labor, attending the care of the cows and the manufacture and sale of the product, at the present prices of milk and butter, there is but little profit to be realized in feeding cattle which produce less than the cows in this experiment. As the question of net profit depends upon constantly varying conditions, no computation is attempted here. It may be stated, however, that, when milk can be produced for 1.8 cents per quart and butter for 12.45 cents per pound on winter feed when prices are at the maximum, there is still some money to be made in dairying with good cows and reasonable ability in buying and selling.

THE MAINTENANCE RATION OF CATTLE.*

BY HENRY PRENTISS ARMSBY.

The determination of the amount of food required to maintain an animal without gain or loss of weight and in unchanged bodily condition is important from two points of view. First, it is sometimes desirable to know the minimum amount of food necessary to maintain an unproductive animal either over winter or at some other time when conditions are not such as to warrant productive feeding. Were this the sole object to be attained, however, it would hardly warrant very extensive experiments, since the skilled feeder will readily determine for himself, in any particular case, the quantity of food required. The second point of view, however, is of greater importance. While the good stockman avoids, so far as possible, the feeding of unproductive animals, yet he must supply to any animal which he feeds the amount of food required for its maintenance throughout the whole feeding period and before any production can take place. It is important, therefore, both practically and scientifically, that he know what proportion of the food which he gives his animal is required for simple maintenance and what proportion of it is available to produce meat, milk, wool or work. Moreover, we cannot make an accurate and scientific comparison of the food with its effects when we take account of only one effect, namely, production, and neglect the other, namely, maintenance.

This fact was long ago pointed out by Henneberg, who in conjunction with Stohmann, instituted experiments forty years ago to determine the maintenance ration of cattle. For many years the results of these experiments constituted our chief data upon this point and upon them was based the feeding standard for maintenance propounded by Wolff and which is included in the table of feeding standards on page 47 of this report.

Practically, the function of the maintenance ration is to keep the animal warm and the food given it may, therefore, be looked upon in the light of fuel for the animal machine. The maintenance ration may accordingly be expressed either in pounds of digestible matter, as in Wolff's standard, or in the equivalent amount of heat which it is capable of giving off in the body of the animal. Calculated in this latter way, Henneberg & Stohmann's experiments appeared to show that mature cattle, weighing 500 kilograms per head (1,100 pounds), required for maintenance sufficient digestible matter to furnish about 16,700 Calories of heat in twenty-four hours, the Calorie being the amount of heat required to raise the temperature of one kilogram (2.2 pounds) of water one degree centigrade in temperature. This amount was increased somewhat by Wolff in formulating his feeding standard because Henneberg and Stohmann's experiments were made in a stable kept warmer than is usually practicable in winter. His standard corresponds to 18,540 Calories of heat.

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*In previous reports, mention has been made of work in progress upon the maintenance ration of cattle. The results of this work have been reported in detail in Bulletin 42 of this Station, which is reprinted as a supplement to this report. That bulletin presented the results of the experiments from a scientific standpoint. The object of the present article is to give a summary of the main results of this work in a more concise and popular form.

At about the time when the German feeding standards first began to attract attention in this country, experiments were published by Sanborn, then superintendent of the New Hampshire Agricultural College farm, tending to show that Wolff's standard for maintenance was too high. In a considerable number of experiments, covering several years subsequent to 1879, Sanborn published results confirming his first conclusions, he being able to secure fair gains in many cases with rations smaller than were called for by Wolff for simple maintenance. Other experimenters also reported similar resuts, particularly Caldwell, at the Cornell University Experiment Station, in 1882-4. In 1887, the writer, in conjunction with Frear and Patterson, carried on a digestion experiment at this Station,* which, incidentally, afforded some data regarding this subject. Two steers were fed for thirty-five days upon corn stover. During this time, the lighter steer gained slightly in weight while the heavier one lost. The available energy of the two rations was calculated to be, for the lighter steer, 13,766 Cal., and for the heavier one 12,533 Cal.

Neither Sanborn's experiments nor the others above quoted were conclusive, since the methods employed were but approximate, yet they strongly indicated that the earlier German results might need revision and our own experiments were undertaken to test this point as carefully as possible with the means at our disposal.

The general plan of the experiments was to determine by trial a ration which would suffice to maintain the weight and general condition of the animals unchanged for a considerable period and then, in a special digestion trial, to determine just how much food was actually digested out of this ration by the animals. The experiments were all made on the same three steers, and extended over four seasons, namely, 1892-3, 1893-4, 1894-5, 1896-7. In all, the experiments covered 718 days, the results upon 157 of which, however, were rejected as probably untrustworthy, leaving a total of 561 experimental days upon which to base conclusions. Each animal and its feed was weighed daily and during most of this time the amount of water consumed daily was also determined. During longer or shorter periods in each experiment, the feces and urine of the animals were collected, weighed carefully, sampled and analyzed, thus affording data for the determination of the digestibility of the food and for the gain or loss of flesh (nitrogenous tissue) by the animals. Since the Station does not posses a respiration apparatus, it was impossible to determine exactly the gain or loss of fat, but approximate conclusions as to this were deduced from the comparatively slight gain or loss of live weight during the relatively long experimental periods.

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*Annual Report, 1887, p. 144.

For the general plan of the experiments and for the discussion of the results, the writer is responsible. The details of the stable work of the experiments, including the weighing, collection and sampling of food and excreta, the weighing of the animals and the temperature observations were in charge of Mr. Wm. H. Caldwell, Assistant Agriculturist of the Station, during the years 1892-3 and 1893-4; of Mr. E. H. Hess during 1894-5 and of Mr. R. J. Weld during 1896-7. The chemical analyses of food and excreta were performed under the direction of Dr. William Frear, Chemist of the Station, by Messrs. J. W. Fields, W. S. Sweetser, J. A. Fries, M. E. McDonnell, M. S. McDowell and C. W. Norris, Assistant Chemists. The calorimetric determinations in food and excreta were made in the laboratory of the Storr's School Experiment Station at Middletown, Conn., by the courtesy of its director, Dr. W. O. Atwater, under the immediate supervision of the chemist of the Station, Dr. C. D. Woods, on samples furnished by us.

For our present purpose, it is unnecessary to enter into the details of the experiments, but a single example, taken from the experiments of 1894-5, may serve to illustrate the manner in which the results were reached. In this experiment, the animals received fourteen pounds per day and head of nearly clear timothy hay. Samples of this hay were carefully taken and in them the amounts of nitrogen and also the heat value were carefully determined. The excreta of the animals were also collected, weighed and analyzed in the same way. The results of these determinations upon Steer No. 1 are shown in the following tables:

Energy.

Energy of food, ...	24,635	Calories.
Energy of feces, ...	10,962	Calories.
Energy digested, ...	13,673	Calories.

Nitrogen.

Nitrogen of food,		83.47 grams.
Nitrogen of feces,	36.47 grms.	
Nitrogen of urine,	42.33 grms.	
In total excreta,		78.80 grms.
Gain by body,		4.67 grms.
Equivalent proteids,		29.19 grms.
Equivalent "flesh,"		131.50 grms.

The above figures show that the digested portion of the 14 pounds of timothy hay contained the equivalent of 13,673 Calories of heat, and that on this ration the animal received daily 4.67 grams of nitrogen more than it gave off, thus showing that it was gaining slightly in flesh. In Plate X, of the supplement, is shown graphically the live weight of this animal during this experiment, the light black line representing the daily weighings and the heavier red line the average weight for periods of ten days. The diagram plainly shows that on the whole the animal was gaining slightly in weight and the broken black line is taken to represent the average rate of gain. From this diagram, we compute an average gain in live weight of 4 kilograms in 80 days, or 50 grams per day. Aside from small amounts of ash, this gain must have consisted substantially either of flesh with its accompanying water or of fat. The table given above, however, shows that there was a gain of 131.5 grams of flesh per day and accordingly there must have been a loss of fat as shown in the following table:

Average weight, December 20,	448 kgs.
Average weight, December 10,	452 kgs.
Gain,	4 kgs.
Gain per day,	50.0 grms.
Gain of "flesh,"	131.5 grms.
Computed loss of fat,	81.5 grms.

The result of the feeding, then, was a gain of flesh and a loss of fat. Without going further into details, we may draw up the following balance sheet, showing the amounts of energy received by the body and given off from it. In this estimate, of course, the loss of fat from the body is considered as an addition to the food, since it was burned up just as the food is; on the other hand, the gain of flesh by the body is counted with the excreta since it is just so much withdrawn from the needs of the body.

Balance of Energy.

	Ingesta—Cal.	Excreta—Cal.
Food,	24,635	
Loss from body, fat (estimated),	773	
Excreta:		
Feces,		10,962
Urine,		816
Methan (estimated),		1,636
Gain by body, proteids,		167
For maintenance,		11,827
Total,	25,408	25,408

The above table shows that the animal in this experiment received 11,827 Calories more of energy than it gave off in the excreta and this, consequently, represents the amount of energy given off in the form of heat from the food which was burned up in the body, or, in other words, represents approximately the amount of energy required for the maintenance of the animal. The results of the other experiments of the series were calculated in substantially the same way and the following table contains a summary of the results, calculated to the uniform live weight of 500 kilograms (1,100 pounds).

Maintenance Rations.

	Stable Temperature. Degrees F.	Steer 1. Cal.	Steer 2. Cal.	Steer 3. Cal.
Experiment I,	About 50,	12,260	13,780	11,650
Experiment II,	About 50,	12,000	12,460	11,400
Experiment VI,	About 48,	12,690	12,510	12,730
Experiment VII	About 57,	13,110	12,620	16,040
Experiment VIII,	About 57,	11,470	10,240	10,800
Average of I, II, VI, VII and VIII,	About 52.4,	12,306	12,322	12,524
Average of I, II, VI and VII,	About 51,	12,515	12,843	12,955

During the progress of these experiments, there appeared a report on the very elaborate experiments of the same character made at the Moeckern Experiment Station by G. Kühn and his associates and later by his successor, Kellner. These experiments were made with the help of a respiration apparatus and, therefore, with a degree of accuracy not attainable in our work. The following is a summary of their results, calculated, like the above, to the uniform live weight of 500 kilograms.

Kuhn's Experiments.

Ox II, Period I,	13,168 Cal.
Ox III, Period I,	12,666 Cal.
Ox IV, Period I, a,	12,350 Cal.
Ox IV, Period I, b,	13,497 Cal.
Ox V, Period I,	11,616 Cal.
Ox VI, Period I,	11,679 Cal.
Ox XX, Period I,	14,009 Cal.

Kellner's Experiments

Ox A,	12,862 Cal.
Ox B,	14,717 Cal.
Average of all,	12,952 Cal.

The above experiments were made exclusively upon coarse fodder, as was also the case with our own with the exception of Experiment VIII. Omitting this for the present, the general average of the two series of experiments is as follows:

	Stable Temperature.	Maintenance Ration.
Our experiments,	51° F.	12,771 Cal.
Kühn and Kellner,	61° F.	12,952 Cal.

The agreement between the general results of the two series of experiments is surprisingly close.

In computing the results of both these series of experiments, allowance has been made for the energy carried off in the marsh gas which is a product of the digestive process in ruminants. Such an allowance was not made in computing the results of the earlier experiments. If we make an estimate of its amount and subtract it from the figures previously given, we have the following as the results of earlier experiments:

	Stable temperature. Degrees F.	Maintenance ration. Cal.
Henneberg & Stohman,	60	14,282
Armsby, Frear & Patterson	50	11,415
Sanborn (average),	?	12,441
Wolff's Standard,	?	16,244

While there is more or less variation in these results, as well as in those upon individual animals, we may fairly conclude as the general result that a daily ration composed exclusively of coarse fodder and containing, per 500 kilograms live weight, about 13,000 Cal. of available energy will suffice to maintain a mature steer under average conditions. It would thus appear that Wolff's standard is probably somewhat high, except perhaps for very cold stables or under unfavorable conditions.

Certain incidental results of some interest were obtained in the course of these experiments. Among the most prominent of these is the confirmation of the results of G. Kühn, showing that the same animal may digest its food to a somewhat different extent at different times. The experiments of 1894-5 were conducted in such a manner as to be practically continuous digestion experiments. In Plate XVII of the supplement is shown, by the heavy red lines, the digestibility of the air-dry matter and of the nitrogen of the food computed in ten-day averages, while the horiontal line shows the average digestibility for the whole period. It is apparent that there were considerable fluctuations in the digestibility at different times. Moreover these fluctuations exceeded the limits of probable error as indicated by the shaded portion on each side of the horizontal line and may, consequently, be regarded as significant and as showing real differences.

Our results also permit of the computation of the available energy of the rations, and particularly of the timothy hay used in most of the experiments. Taking the average of all the determinations, we find that each gram of dry matter in timothy hay yielded 1.91 Calories of energy for the use of the animal. Of the total heat-value of the hay, as found by direct combustion, 43.62 per cent. was available for the animal, while the remainder was thrown off in the various excretory products. The percentage distribution of the energy of the food in our experiments and also in Kellner's was as follows:

PERCENTAGE DISTRIBUTION OF ENERGY.

	Timothy Hay. Per cent.	Meadow May. (Kellner.) Per cent.
In feces,	47.27	41.8
In urine,	2.61	6.1
In Methan,	6.50	7.3
Available,	43.62	44.8
	100.00	100.00

APPLES IN PENNSYLVANIA.

BY GEORGE C. BUTZ.

The planting of extensive apple orchards in Pennsylvania is now being witnessed in several sections of the State. The many inquiries coming to the Station concerning apples—the varieties, cultivation, treatment of diseases, insects, etc.—call for this bulletin, touching upon these matters in a brief and concise manner. The ordinary orchard of this State and its management in the past affords but little encouragement to the young farmer who is estimating the probability of profitable returns from an apple orchard. He sees too many trees that bear fruit for which there is no market. These are summer or fall apples. He sees, also, trees which he knows have not yielded a reasonable crop within his memory. He has learned, too, that so much of the fruit is wormy and scabby and is, therefore, refused by the large dealers in fruit. Nevertheless, it is well known that there are definite causes of these and other adverse conditions which can be easily avoided by a careful study of the principles of fruit culture.

The counties in which the greatest activity is displayed in the planting of apple trees on a large scale are, from present advices, the following: Adams, Allegheny, Armstrong, Beaver, Bedford, Berks, Centre, Clearfield, Clinton, Crawford, Cumberland, Dauphin, Erie, Franklin, Huntingdon, Indiana, Lancaster, Lawrence, Lebanon, Lycoming, McKean, Mercer, Schuylkill, Somerset, Warren, Westmoreland and York. Many good apples have, for years, been produced in these counties in the ordinary farm orchards, a long list of varieties has been thoroughly tested and several very excellent varieties have originated here. Summing up the testimony of the experienced fruit growers of the State, it is evident that with the proper selection of varieties, attention to cultivation and care in handling the crop, as fine apples can be produced in Pennsylvania for the markets of the world as are shipped from our neighboring States. In a letter, dated April 9, 1898, from Woodall & Co., Liverpool, England, fruit brokers, valuable testimony to this fact is given.

"In reply to your favor, we beg to inform you that some Pennsylvania apples have arrived here during the past season, consisting mostly of Ben Davis variety, and a few York Imperials, the quality and condition of which have been satisfactory and compare favorably with other growths. The latter variety is a favorite one and has a good future before it, on account of its color and good carrying properties. At the moment, apples are very scarce, and Ben Davis are realizing up to 27 s. ($6.75) per barrel, which would be about the value of York Imperials."

The foreign markets are becoming an important outlet for the surplus apples grown in America. In the statistical diagram published by Woodall & Co., the total import of American and Canadian Baldwins into Great Britain for the year ending June, 1897, was 2,720,000 barrels.

The statistics furnished by the U. S. Department of Agriculture show that the exports of apples from the United States for the five years ending June 30, 1897, were as follows:

1893,	408,014 barrels.
1894,	78,580 barrels.
1895,	818,711 barrels.
1896,	360,002 barrels.
1897,	1,503,981 barrels.

Markets for American apples are being opened up in several foreign countries, and our home consumption could be greatly increased by proper care and handling.

SOIL.

The error which has been commonly made in locating orchards in the past, is in choosing a poor piece of ground; one that was thin, or rocky, or on a hillside, too steep to cultivate. The modern practice in choosing soils for apples is based upon the fact that *no soil is too good for an orchard.* Of course, low, flat, meadow land is not suitable for tree growth. It tends to cause the production of much brash wood and the fruit does not have the color and flavor of that produced in well drained land. The serious objection to such low land is in that it holds stagnant water below the surface. Fields might be quite level, and if somewhat elevated and well drained, either naturally or artificially, they would be first class for successful orcharding.

Sandy soils are not adapted to the apple; they do not possess or retain the fertility necessary for the best growth of the apple tree. The limestone soils of the State are among the best for apples; they are firm enough to prevent damage to the roots in winter, and they sustain the life of the trees to a good age. Such lands occur in York and Lancaster counties, abound in the Cumberland Valley and extend in a broad band to the northeast through Lebanon, Berks, Lehigh and Northampton counties. It also constitutes much of the tilled land in the valleys west of the Susquehanna river. The red shales and sandstone soils, more especially those showing trap rock, are the favorite fruit lands, forming an extensive band from Adams to Bucks counties. West of the Allegheny Mountains are the carboniferous formations with a variety of soils. The gravelly clay loams are abundant, producing an excellent quality of apples. The acreage in this section is rapidly increasing, and will soon command the attention of buyers.

Long keeping quality is claimed for the apples of the northern counties, where the Northern Spy is still a successful variety. On the other hand, in the southeastern counties there is not yet found a satisfactory apple to be grown for late winter use. There, the Baldwin commonly falls in September.

A soil intended for apples should be first tested with some annual crop, as corn or potatoes. If a good yield is obtained, it may be assumed that the ground is fit for the trees; if not, it should be kept under cultivation with judicious fertilization until it is in good condition. This might be considered as the preparation of the soil; it will insure a good "mechanical" condition, and guard against an error frequently made of planting in a poor soil.

TILLING THE SOIL IN YOUNG ORCHARDS.

Whatever has been the previous treatment of the soil, in the spring before planting, it should receive an application of barnyard manure, at least twenty two-horse loads to the acre, the soil being carefully plowed, eight inches deep, and pulverized by harrowing.

During the first three or four years, it is absolutely necessary to till the orchard ground in order to procure a thrifty growth of the trees. Without it, the best stock will become stunted and the time of fruiting will be delayed. This much of the new system of cultivating commercial orchards has been generally admitted, as is shown in our modern practice. During these few (six to eight) years, certain crops may be grown in the orchard and some return may be secured for the labor expended, but the crop selected should always be one that will require or admit of cultivation. Hay or grain should never appear in the orchard. Generally, it may be said, that strawberries, bush fruits, potatoes, beans or corn might be grown in the orchard, providing fertilizer is supplied for these crops and sufficient clear space is left about the trees. The growing of corn to shade the trees is an unnecessary practice in Pennsylvania.

CULTIVATION IN BEARING ORCHARDS.

If the annual plowing and cultivation of land has been properly practiced in the young orchard, it is an easy matter to continue the custom. The advantage of such tillage over the old sod treatment can be fully realized only by practicing it for a few years. It serves to maintain the vigor of the trees, and upon this depends long life, good yields and perfect fruit. The work of the year consists in plowing in early spring, then harrowing with a spring-tooth harrow at intervals until July, when it is best to cease tillage to insure the ripening up of the newly formed wood and buds. At this time some cover crop, such as crimson clover, red clover, cow pea, or even rye, might be sown. Such fall growth will add plant-food and improve the general condition of the soil when plowed down the succeeding spring.

Orchards which have been long standing in sod may be improved by plowing and cultivating, but not in all cases. One standing in sod and bearing satisfactorily may not be benefited by plowing, but one which is unprofitable should be thus treated as a first remedy. Plowing should be shallow to avoid the roots; in some instances, only the harrow could be admitted, and should first be used when the ground is soft in the spring, and its use continued through the season. Where sod cannot be avoided, the best antidote is to pasture it with hogs or sheep.

FERTILIZERS.

The purpose of applying fertilizers to land is to improve the condition of the plants grown there. Consequently, what should be applied must be determined by a careful diagnosis of the case. It is certain that many orchards are improved by a judicious treatment with fertilizers. Barnyard manure is our ordinary fertilizer, and is a most excellent one for trees which have lost vigor. It should be applied in the fall or winter, at the rate of from five to ten two-horse loads per acre, every three or four years. If productiveness or the quality of the fruit is to be increased, then an application of 200 pounds of muriate of potash, with 100 pounds of South Carolina rock should be made. Some successful orchardists have made heavier applications of plant food and consider the benefit proportionally greater. Every grower must work out by trials upon his own land the answers to the question: What should be applied? and what quantity is best?

THE TREES.

The best trees to buy are those which are two years old from the bud, with straight stiff trunks, abundant "fibrous" roots, of medium size, not stunted and free from insects. It is better to pay twenty cents for such a tree than ten cents for one which does not measure up to this requirement. Buy from a local nurseryman if he possesses the stock you want, and in good shape. Thrifty trees grown nearby are more likely to give satisfaction than those reared in a distant section of the country. A personal acquaintance with a nurseryman, an inspection of stock before ordering and short shipping distances are advantages not to be overlooked. Orders for trees should be placed in the fall or early in the winter to avoid hasty decision and substitution of varieties.

PRUNING AT TIME OF PLANTING.

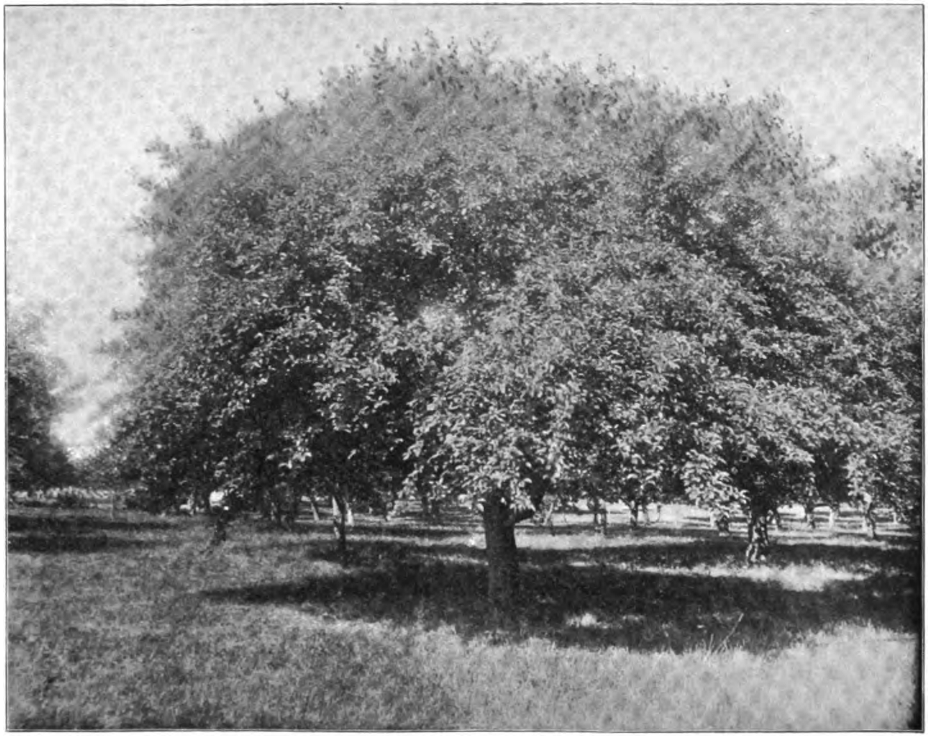
So frequently apple trees are planted in the orchard without any pruning, because they seem to possess a clean trunk and a well-formed head. Sometimes the bruised ends of large roots are cut away, which, indeed, should never be neglected. Planters should realize that in taking up trees from the nursery row, the root system is necessarily reduced, probably one-half or even two-thirds, and it would seem reasonable that the top should be correspondingly reduced. As a matter of fact, many buds on the thrifty branches are so developed that they would burst into foliage if left on the tree, producing an extensive leaf surface from which moisture is evaporated more rapidly than it can be supplied by the reduced root system. Consequently, in a dry time of the first summer the trees would suffer greatly or even die outright. Nurserymen use the pruning knife very freely upon young trees, but the average farmer tries to save all he gets and, therefore, loses much. The proper pruning of an apple tree consists in cutting away all the top except four or five of the best branches and these are shortened to spurs about six inches long.

DISTANCE TO PLANT.

Every detail of arrangement in an orchard should have reference to two leading factors in orcharding—ease of cultivation and most profitable yield. At a distance of twenty feet, apple trees, when they reach maturity, meet in their branches, shade the entire ground and prevent the possibilty of spraying. The typical tree at maturity is one with a perfectly dome-shaped head and this in such varieties as Baldwin, Bellflower and R. I. Greening will extend nearly forty feet in diameter. Such varieties like Northern Spy, Ben Davis and York Imperial, with less spreading heads, may be planted thirty feet apart, or, better, thirty-five feet. It must be admitted that on the poor hillsides so commonly chosen for the farm orchard, twenty-five feet seems a sufficient distance for any variety; but we are not considering in this bulletin that style of orchard. Our best soils are not too good, and will develop larger trees with longer life than the waste lands of the farm.

PRUNING BEARING TREES.

When we pass from orchard to orchard we are impressed with the fact that much bad work has been done with the pruning saw. Many trees are stripped of their lower branches and only three or four upright limbs rise from the trunk, and nothing short of a ten-foot ladder would make it possible to reach any fruit. Again, we see the effect of utter neglect of pruning, in trees whose tops are a tangle of branches and water sprouts. There are some trees which require little or no pruning after they have reached the bearing age, because of their symmetrical growth, while others require some attention annually to keep them in the best shape for growth and fruit. There is nothing mysterious about pruning. It is only necessary to regard



A well-formed Apple Tree Spreading 35 Feet.

the several reasons for it to do it properly. 1st. To remove all dead wood. 2d. To thin out interfering or crowding branches, to let light into the fruit bearing portions of the tree. 3d. To maintain the symmetry of the tree. It is better to prune away small branches frequently than large limbs, which have been long neglected.

TOP GRAFTING OR DOUBLE WORKING.

A practice is springing up in some apple sections of planting seedlings or budded stock of some variety making thrifty straight growth, maintaining a sound trunk and when these trees are well established in the orchard ground, say in two years, they are top grafted or budded with the varieties to be fruited in the orchard. In Vermont, Prof. F. A. Waugh, says, native stock, top-grafted, is thought to make hardier trees for exposed situations than the ordinary low budded stock from the nursery, and that one grower plants all Tallman Sweets and top grafts. Prof. Bailey, of New York, recommends Northern Spy for stocks. For Delaware, G. Harold Powell recommends Ben Davis for winter varieties and Red Astrachan for early apples. Northern Spy is a clean, straight, thrifty tree, and could be profitably used in Pennsylvania. The Tallman Sweet has the same vigorous growth. The advantages claimed for this practice are: More uniform trees, earlier fruiting, longer life for certain varieties and the opportunity of selecting all buds or cions from particular trees of special merit for the quality and quantity of their fruit.

There are many midde aged trees in good health, which would be better if top-grafted with more profitable varieties, and orchards be thus greatly improved.

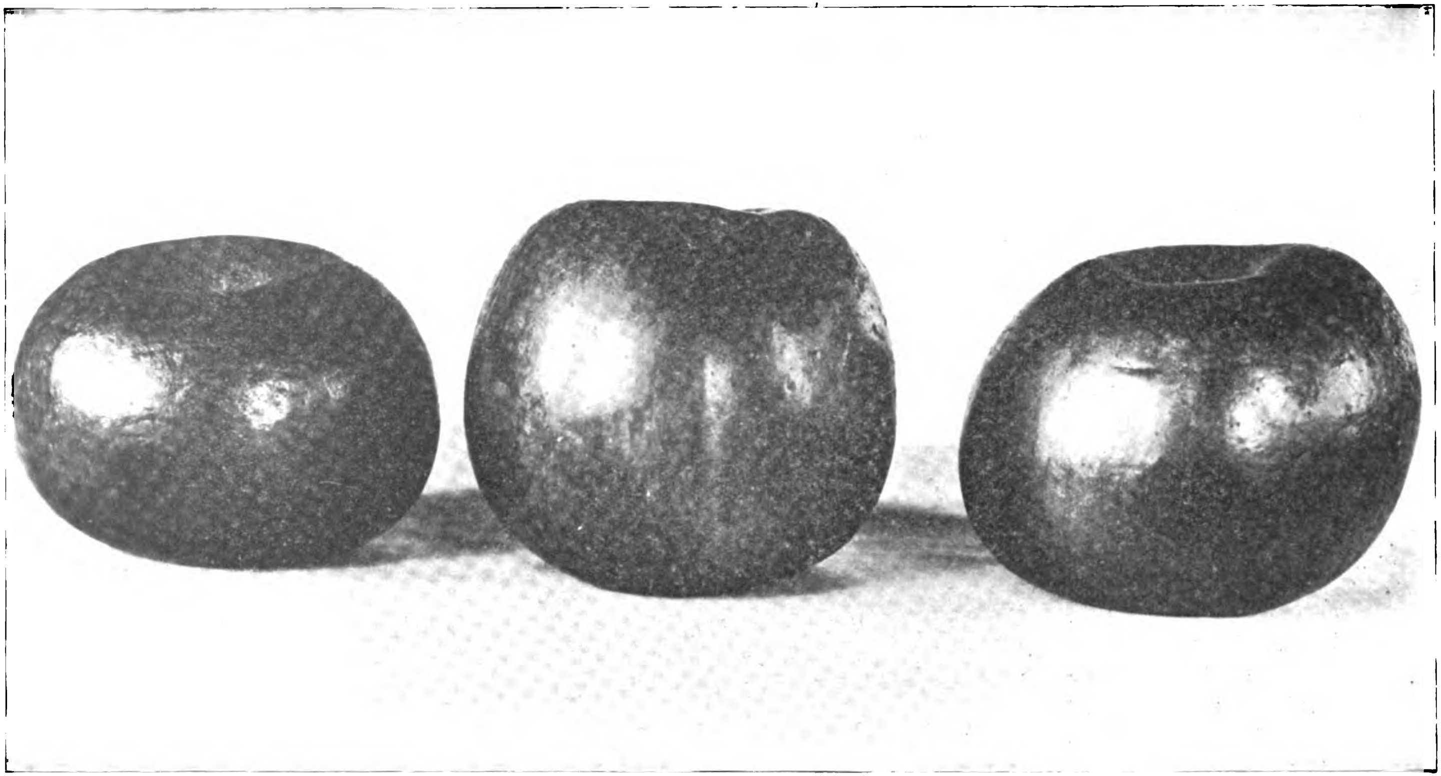
CHOICE OF VARIETIES.

The most frequent query which comes to the Experiment Station about the apple is concerning the best variety to plant. The advice usually given in reply is, to consult the neighboring orchards and select upon the basis of local experience. This is the most satisfactory method of solving the problem, only with reference to the varieties which happen to be in the local orchards. There are, however, certain varieties of apples which have the necessary traits of a profitable commercial variety, such as early fruiting, heavy bearing, good color, size and keeping quality, varieties which have already a reputation in the markets. Each planter must work out the problem of "best varieties" from a number of circumstances which he alone can properly estimate. There is so much variation in the soils of the State that the same list of varieties would not succeed equally well in all sections. In 1888, the State Horticultural Association prepared, through the aid of correspondents, a list of the ten best varieties of apples for market in each county of Pennsylvania. More than one-half of the counties placed Baldwin as a first choice. The other nine varieties were in order of prominence, Northern Spy, Greening, Fallawater, King, Ben Davis, Smith's Cider, Bellflower, Twenty Ounce, Newtown Pippin. This list would be greatly modified, if revised at this date. For many orchardists have discovered that since the Ben Davis apples of the west have made a reputation in the markets, Pennsylvania has a variety of superior quality, better color, equal productiveness and that keeps as long. This is the variety referred to in the letter of Woodall & Co., as "a favorite," namely, the York Imperial. It originated in York county and, therefore, is peculiarly a Pennsylvania apple. The prospect is now good for this State to become prominent for its yield of York Imperial apples. There are extensive orchards, principally of this variety, in York, Adams and Cumberland counties—some quite young, others just in bearing. It has been highly recommended in the northern and some western counties. It is being planted largely in New York, Ohio, Illinois, Virginia, Maryland and Delaware. In Kansas, it is growing in popularity. E. J. Holman, of Leavenworth county, Kas., said of it last December at a meeting of the Kansas State Horticultural Society: "The York Imperial is new to many of us, because of its late sudden popularity. It has been sent to Europe, holding its own with Missouri Pippin and others. It is large, a good keeper and growers always seem pleased with it. It seems to be growing popular."

Our fruit growers have been contending that we have no variety of apples that is well suited to commercial orcharding in Pennsylvania, and yet in the face of this contention, other States have taken up the York Imperial and made for it a reputation.

It is encouraging to be able to report, however, that in Adams county, there are about 200 acres of apples in bearing condition, the principal varieties being York Imperial and Ben Davis. There are also about 400 acres of younger orchards in that county in which York Imperial predominates. This apple is highly recommended for great profit by such experienced fruit growers as Hon. G. C. Brown, Yorkana; Hon. S. B. Heiges, York; Noah Sheely, Cashtown; John Shull, Cashtown; Samuel Graham, Biglersville, and C. W. Good, Waynesboro.

I have purposely said much in favor of the York Imperial, because it has seemed to me that its value as a money maker has not been fully appreciated. It is a common error, when discussing varieties to bring forth a long list of very good apples which are good only in consideration of the fruit, its flavor, color, size and keeping qualities, and when we consider the respective trees, we declare them unsatisfactory because they are poor growers, light bearers, susceptible to diseases, etc.



York Imperials.—**Showing Three Distinct Forms Often Occurring on the Same Tree.**

In this connection, I will make a brief description of such varieties of winter apples as might be considered as candidates for the commercial orchard in this State.

York Imperial.—Sometimes listed in catalogues as Johnson's Fine Winter, and in its native county sometimes referred to as the Shep apple, Shep being a word of the Pennsylvania German having reference to the oblique shape of the fruit. The tree is a vigorous grower with slender drooping branches after the manner of Ben Davis. It comes into bearing at four years from planting, bears regularly and heavily. The foliage and fruit are remarkably free from scab. The fruit is of medium size, oblong, angular, oblique, smooth, skin yellow and almost wholly covered with two shades of red, the darker one disposed in indistinct stripes; basin deep; cavity deep and narrow, stem short; flesh yellow, juicy, firm, sub-acid, good; season, late winter. A good shipper, bringing high prices.

Baldwin.—This variety needs no description. There are many sections of the State where this apple is grown with profitable returns particularly in the western and northern counties.

Jonathan.—This variety is a heavy bearer, often too heavy, causing small fruit; size, medium to small; skin, nearly covered with stripes of brilliant red on a pale yellow ground. Flesh white, very juicy, spicy, moderately rich; keeps through winter. A New York apple, recently come into favor in some sections of Pennsylvania.

Smith's Cider.—A favorite fruit for near markets in Montgomery, Bucks, Chester and Lancaster counties. Medium to large. Shaded or slightly striped with light red on pale greenish yellow; often quite green or lacking red coloring; frequently smutty. Flesh, whitish, tender and crisp; sub-acid. A native of Bucks county.

Stark.—A vigorous, upright and spreading tree. Fruit large, roundish. Nearly the whole skin is covered with two shades of dull dark red; the dull color is an objection. Many light brown dots. Stalk, short. Flesh, yellow, a little coarse, moderately juicy. Good. Season, January to May. Recommended in southern and western counties.

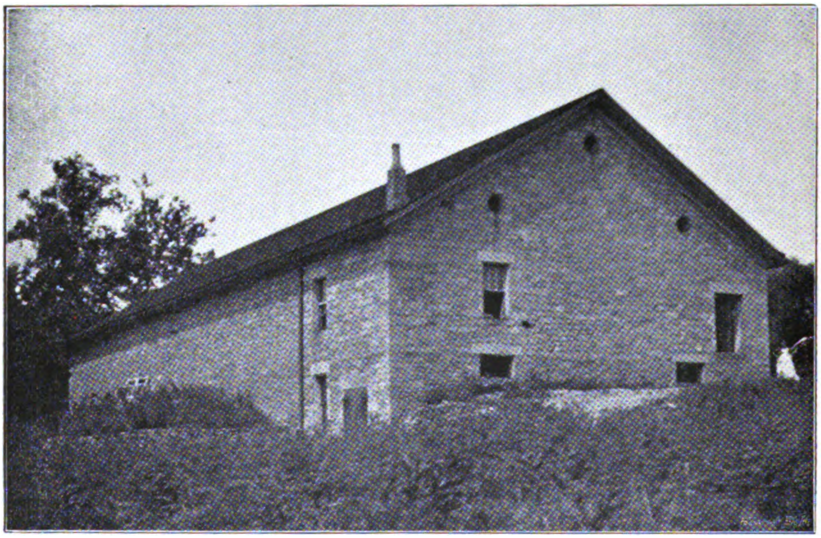
Ben Davis.—This variety is largely planted in this State, but the quality of fruit is inferior to that grown in the west. That it seems unwise to attempt to compete with the western product.

Fallawater.—The Pennsylvania apple, known also as Pound and Tulpehocken, is a profitable commercial variety in Lancaster and Berks counties, because of its uniform productiveness.

Self-sterile Varieties.—In planting extensively of a few varieties of apples, it is not advisable to plant each variety in a solid block, where it must largely depend upon its own pollen to set its fruit, because of the frequency of self-sterility among the varieties of the apple. According to the work of Waite & Fairchild, the following apples are more or less self-sterile: Bellflower, Shenango (Strawberry), Gravenstein, King, Northern Spy, Norton Melon, Primate, Rambo, Red Astrachan, Roxbury Russet, Spitzenburgh, Talman Sweet. Varieties mostly self-fertile: Baldwin, Codlin, Greening. If but two varieties are planted, three or four rows of the one should alternate with one or more rows of the other, as in planting staminate with pistillate varieties of strawberries.

PRESERVATION OF APPLES.

The essential conditions of successful winter storage of fruit are a low, even temperature, with a dry atmosphere. The temperature should be held as near 32 degrees F. as possible, and with the smallest possible range of variation. By a dry atmosphere is meant the absence of that dampness which favors fungus growth. Since the introduction of the manufacture of ice, it has been possible to maintain very uniform conditions in apartments used for cold storage, and the determination of certain questions has been made easy. The most perfect and the most extensive cold storage house is in Boston, Mass., and one modeled after it is located at Rochester, N. Y. The temperature of the apartments is reduced by means of an ice plant, but unlike the ordinary arrangement, the cooling pipes are all confined in a room separated from the storage apartments. The very cold air is then admitted into the latter rooms through wooden conduits. This ensures a more perfectly dry atmosphere. The experience at these large establishments indicates that apples are more successfully preserved in a constant temperature of 30 de-


Cold Storage House of W. F. & R. Brown, Hancock Co., W. Va.—(*Corbett.*)

grees F. than at any other degree. The capital required to construct such a storage house puts it beyond the reach of even the wealthiest fruit grower; therefore, he must be content with an arrangement perhaps less perfect. There are, within our State, several fruit houses, built of stone, at a cost of from $2,000 to $5,000, having capacity for one to three thousand barrels. Such houses are kept cool by storing large quantities of ice on the upper floor. One of these is on the farm of H. S. Gable & Bro., Boyertown, in Berks county, having a floor dimension of 25x40 feet, the fruit room being 12 feet to the ceiling, and having a capacity for 1,000 barrels. The cost of this house was $3,000, but stones had to be brought a great distance, making the expense of building unusually high. There is a convenient arrangement at this place for ice. The house is built on rising ground, so that in the rear is constructed a dam almost on a level with the ice floor in the fruit house. This dam is fed from a small stream, and the ice is drawn directly into the house. A house of this character is illustrated on page 80. It has two cold chambers, with capacity for 10,000 barrels in the basement and an ice chest of large capacity in the second story. It is on the farm of Wm. F. & Robt. Brown, Hancock county, W. Va.

Fruit houses are built also of wood, because the cost of construction is much less. The walls are made of ordinary studding, sheathed within and without; the intervening space is sometimes filled with saw dust. The exterior surface is then covered with a good building paper and weather-boarded.

Fruit caves or cellars are usually of smaller dimensions than the houses and are less easily controlled in reference to temperature, there being no provision for ice. A substantial cellar built by Hon. G. C. Brown, Yorkana, York county, has a capacity of 200 barrels. The floor dimensions are 12x20 feet; the walls and arched roof are of stone, cemented inside and outside. An excavation of six feet was made, and the ground removed used to cover over the top.

It is the conclusion of the New York fruit men that apples will keep much better if they are hurried into cold storage as promptly as they are picked instead of being left in the orchard on piles or in barrels to sweat.

SPRAYING.

The operation of spraying apple trees is slowly becoming a practice in this State. Our farmers have not accustomed themselves to depend upon the income from the orchard, or even to count upon any material return when a crop "comes," therefore, they have not been willing to make a slight investment to insure a clean crop, or protect the health of their trees. Queries concerning spraying are becoming more numerous and the real value of thorough work is better appreciated now than formerly. The two great enemies of the apple are the codling moth and the apple scab. For the former, we have a specific remedy in Paris green; for the latter, it is the fungicide, Bordeaux mixture, upon which we must depend.

These two materials, sprayed intelligently upon apple trees, not only protect the fruit against its enemies, but also protect the trees themselves. The best outfit for doing thorough work in spraying is one in which a platform is raised high enough for the man who guides the nozzle, to thoroughly cover the topmost branches. Such a platform may be safely raised ten feet above the axles of a wagon.

INSECT ENEMIES.

There are but few insects which cause serious damage to apples in Pennsylvania. The fact is that only two, the Codling-moth, or apple-worm, and the Apple Tree Borer, are present in every orchard, doing great damage. The apple aphis, oyster shell bark louse, scurfy bark louse, tent caterpillar and a few others are often present, but seldom demand treatment. The canker worm, so destructive to the orchards of New York State, appears to some extent in the counties bordering on that State.

Codling Moth (*Carpocapsa pomonella*, Linn).—Wormy apples are the most common variety of apples grown in the neglected orchard. The fruit is early and late, sweet and sour, yellow and red skinned, but is not first class for dessert or cooking at any season of the year. It is not necessary to give here a description of the little grayish brown moth, which we seldom see, or of the larva which every one who has eaten an apple has seen. In view of our most practical remedy for "wormy apples," it is necessary for us to remember that the moths lay their eggs, which look like little drops of milk* on the "surface of the young apple, its stem or even on the adjacent leaves." The time of depositing eggs begins about one week after the blossoms have dropped and lasts about three or four weeks. The worms hatching from these eggs mostly crawl into the calyx to enter the fruit, a few enter at angular points outside of the calyx.

Remedy.—The use of straw or coarse paper bands about the trunk of the tree was the most effectual treatment for the codling-moth ten years ago. This is now just a full step behind the age, for it seeks to catch the worm after it has accomplished its destruction to the fruit. The modern treatment aims to save the fruit by destroying the worm at the beginning of its life. This is done by spraying the trees with Paris green, before the calyx has closed, to store up therein a dose of poison for the young worm when it comes to enter the fruit. One or two sprayings within ten days after the petals have dropped are all that is necessary. This cannot insure the destruction of every worm, but will very greatly decrease the number of wormy apples. There is a second brood of larvae coming irregularly late in summer, but it cannot be successfully treated. If, however, the spraying has been thoroughly done in June, the chances for many worms in the second brood are greatly reduced.

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*Slingerland, Cornell Exp. Sta. Bul. No. 142.

Borers.—The round-headed borer and the flat-headed borer, chiefly the former, are very destructive to apple trees. While few trees are killed outright by them, many are crippled for life. The borers are found usually at the base of the tree-trunks feeding in the sap wood. The best method of fighting these insects is to visit each tree in the early autumn months in search of the borers, and wherever the evidence of fresh sawdust-like casting is found, cut out the borer with a knife or crush it in its burrow with a stiff copper wire. Though many washes have been recommended to prevent the entrance of these insects into the tree, none of them can be fully depended upon to protect the trees. One of these washes frequently used is made by boiling one quart of soft soap (or one pound of hard soap) in two gallons of water, then adding a pint of crude carbolic acid. The application is made with a brush to the trunks of the trees about June first.

Oyster-shell Bark-louse (*Mytilaspis pomorum*, Bouche).—In these days of the scare about San Jose scale, many inquiries are made about this bark-louse in the fear that it might be the newcomer. The resemblance of this scale to the "oyster-shell" is only in shape; in size, it is only one-eighth of an inch long. Apple trees that are not thriving sometimes become seriously attacked by these oyster-shell scales, and small branches are killed by them. In such cases, remedies should be applied. The best treatment is to spray with kerosene emulsion, but it must be done early in June, when the young insects are just hatched out and move about over the branches without the protection of a scale.

Canker Worm (*Anisopteryx pometaria*, Harris).—This insect is scarcely known to Pennsylvania orchardists. It was recently reported to me from Erie county as becoming abundant enough to call for treatment. It is a larva of the "measuring worm" type; in color, from yellow to a dark brown and variously striped. When full grown, it is about one inch long. These worms occur in great numbers and devour the foliage of the apple; in severe cases they strip the tree of its verdure before August. Many methods of fighting this insect in the orchard have been tried. Lodeman* says: "The cheapest and best method to get rid of the pest is to spray the foliage with Paris green or London purple. This should be done early in the season, as soon as the caterpillars make their appearance." One thorough application is ordinarily sufficient.

Aphis (*Aphis Mali*, Faber).—When pruning apple trees, early in spring, we commonly find many small, black, shining oval bodies clinging to the twigs or clustering about the buds. These are the eggs of the so-called "lice" which are often very numerous upon the young shoots and leaves of the apple trees. Frequent inquiries are sent to the Experiment Station concerning this insect. These lice are abundant in April, May and June, disappear in July and reappear again in the fall. They feed by piercing the tender tissue of the new growth and suck out the juices. They thus cause the curling up of the foliage and prevent blossoms from maturing. As a rule, the real damage to a tree or crop of fruit is very slight unless the insects are unusually abundant. Therefore, it is seldom that a remedy needs to be applied.

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*Spraying of plants, p. 250.

Remedy.—When certain trees seem to be badly attacked, and it is desired to destroy the lice, they should be sprayed with tobacco water, or with kerosene emulsion.

Tent Caterpillar (*Clisiocampa Americana*, Harris).—This insect is usually recognized on the apple tree by its forming webs in the forks of branches. The caterpillars eat the foliage during the day and at night, or on dull days, may be found in the web, when it is a simple matter to cut out the whole colony and burn it.

FUNGOUS DISEASES.

Much has been made of the fungous diseases of plants and, in pursuing investigations, a long list of fungi preying upon economic plants have been made prominent. The number of formidable enemies of each cultivated tree or plant has become large, and agriculturists and horticulturists have become alarmed and perplexed. So long, however, as remedies can be found for the diseases, there is no occasion to surrender to the enemies, but a new field of study is opened up to the young farmer and gardener. The apple has its full share of fungous diseases, but there is only one which is universally present affecting the quality and price of the apple crop. This one is the apple scab.

Apple Scab (*Fusicladium dendriticum*, Fckl.).—The black, circular, scabby spots on the skin of apples is as common and familiar as the apple worm. It is not so generally known to fruit growers that the fungus causing this scab, attacks also the leaves of the trees. The diseased leaf shows light green areas which soon are raised as if pressed up from the under side of the leaf; if attacked at several points, the leaf is much crippled. Young foliage in particular, when attacked, is much curled by it. Such foliage often drops from the trees, or at best is of little value to the growth of the tree when in this diseased condition. Not all varieties are attacked equally much by this fungus. Those most freely attacked in the College orchard are Early Harvest, Butter Sweet, Northern Spy, Bellflower and Spitzenberg. The varieties noticeably resistant are Yellow Transparent, York Imperial and Fallawater.

Remedy.—Bordeaux mixture is the specific remedy for most of our fungous diseases. It must be applied as a preventive and not as a cure. For the apple scab, treatment must begin early in the season to be most successful. The mycelium of the fungus has been found growing upon twigs even before the buds have burst. Therefore, it is recommended to make the first application of fungicide just before the buds burst. This time a solution of sulphate of copper alone (one pound to fifteen gallons of water) can be used, as there is no foliage to be injured. All later sprayings are made with Bordeaux mixture; first, just before the blossoms open; second, as soon as the blossoms have fallen. These should be followed by two or three more applications at intervals of about two weeks. This treatment is for the worst cases; the more resistant varieties like the York Imperial would be protected by two applications.

Rust (*Roestelia pirata*, Thax., and *Gyumosporangium macropus*, Link.).—The foliage of some apple trees is spotted with an orange-yellow color, while the surrounding portion of the leaf is normally green. The spots are round, the margins not very definite; in the centre are black dots. On the under side of the leaf, the spots are brown. The tissue in the spots is swollen; cluster cups, containing spores, appear in the spots on the under side of the leaf. The fruit is also attacked by this fungus and is ruined, although this is not very frequent. Large orange colored patches, pierced by the cluster-cups, cover sometimes one-half of a fruit. An interesting feature of this fungus is that it requires two host plants to complete the cycle of its life, as it has two distinct forms of existence. The one just described is upon the apple; the other is parasitic upon the red cedar, producing upon this evergreen tree the well-known "cedar apple." It has been discovered that the spores produced on the apple leaf will not germinate upon the apple, but will upon the cedar and then produce the peculiar swellings which, in May, push out soft yellow horns containing a very different spore. This spore, in turn, will not germinate upon the cedar, but only upon the leaves and fruit of the apple.

It is apparent, therefore, that where the Rust appears we should suspect the presence of red cedars, and by removing them, remove the disease from the orchard. Where this cannot be done, spraying with Bordeaux mixture, as for the scab, is recommended. Red cedars have been used for wind-breaks in orchards; the natural consequence of such a use is now apparent.

Leaf Spot (*Phyllosticta limitata*, Pk.).—This is a new disease of the apple. This fungus causes small round spots in the leaves of the apple. The spots are yellowish brown and appear about the same on both sides of the leaf; the tissue is thin and brittle. The margin of the spot is very definite. In the tissue of the spots may be seen with a hand magnifying glass small black specks in which occur very many oblong spores. This disease was first reported by F. C. Stewart,* who found it in orchards on Long Island. Specimen leaves were sent to me from Lehigh county, in Pennsylvania, bearing this disease; with them came this statement: "The leaves (in early June) drop almost as they would in the fall. They are almost entirely yellow when they drop."

When this disease becomes so destructive in an orchard, remedial measures should be employed to protect the health of the trees. The use of Bordeaux mixture to prevent apple scab will probably be effectual as a preventive of this leaf disease. Making three or more applications, the first just before the blossoms open, the second just after the petals have fallen and one or more, as the case seems to demand, at intervals of two or three weeks.

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*14th Annual Rep. N. Y. State Exp. Station, 1895, p. 545.

SMALL FRUITS IN 1897.

BY GEORGE C. BUTZ AND J. P. PILLSBURY.

STRAWBERRIES.

The planting from which the records were taken for the season of 1897 was made principally in the fall of 1894. All of the varieties after No. 43 were planted later, as follows: Nos. 44 to No. 48, inclusive, and Nos. 50 and 51 were planted in the spring of 1895. Nos. 48, 49 and 52 to 54, inclusive, were planted in the spring of 1896, and Nos. 55 to 58, inclusive, were planted in the spring of 1897.

Varieties.	Plot No.	Flowers. Pistillate marked P.	First flower.	First ripe.	Last ripe.	Yield, scale of 1 to 10.	Leaf-blight scale of 1 to 10.	Runners, scale of 1 to 10.	Vigor, scale of 1 to 10.
Adam's Favorite,	54	P	May 9,	June 10,	July 12,	9	2	9	8
Banquet,	14	P	2,	3,	9,	7	4	3	5
Beebe,	16	....	3,	9,	10,	3	5	2	4
Boynton,	27	P	3,	5,	10,	9	5	2	4
Brandywine,	24	....	7,	12,	10,	7	8	5	7
Bubach,	13	P	Apr. 29,	2,	8,	7	6	4	8
Carrie,	55	....	May 11,	16,	8,	....	4	9	8
Champion,	50	....	9,	12,	8,	5	4	8	7
Chas. Downing,	2	....	2,	3,	8,	3	8	3	8
Crawford,	31	....	4,	5,	9,	8	2	7	10
Crescent,	3	P	6,	7,	9,	10	4	9	8
Cumberland,	8	....	3,	5,	8,	6	7	3	7
Darling,	57	....	....	....	....	....	....	2	6
Dayton,	42	....	Apr. 29,	7,	5,	5	7	10	8
Ella,	56	....	May 5,	....	....	....	4	6	7
Enhance,	35	....	Apr. 29,	10,	10,	7	6	3	4
E. P. Roe,	26	....	May 5,	5,	8,	6	7	1	1
Eureka,	18	P	9,	10,	10,	7	6	5	8
Farnsworth,	38	....	1,	5,	8,	8	8	9	10
Gov. Hoard,	11	....	14,	16,	12,	5	7	5	9
Gandy,	17	....	6,	7,	10,	5	6	5	8
Greenville,	4	P	10,	9,	8,	7	2	8	10
Harrison,	58	....	11,	....	....	....	0	7	8
Hay's Prolific,	49	....	10,	10,	9,	3	2	6	7
Haverland,	33	P	4,	7,	8,	7	4	5	9
Henderson,	32	....	3,	7,	10,	10	7	6	10
Hull's No. 3,	51	....	14,	16,	8,	3	9	7	6
H. W. Beecher	43	....	11,	14,	5,	4	7	8	7
Iowa Beauty.	41	....	7,	10,	8,	7	7	9	8
Kentucky,	10	....	10,	12,	10,	3	8	6	6
Leader,	19	....	5,	7,	9,	7	7	5	7
Luther,	21	....	3,	5,	8,	9	8	4	5
Maida, No. 11,860,	52	....	4,	14,	10,	5	7	7	9
Margaret,	45	....	8,	9,	8,	2	7	7	8
Mary,	40	P	May 6,	10,	10,	10	8	9	10
Meek's Early,	6	....	Apr. 29,	May 31,	June 24,	2	2	7	6
Michel's Early,	15	....	29,	June 5,	July 1,	7	5	5	10
Monarch,	1	....	29,	5,	8,	6	8	4	8
Mt. Joy,	20	....	May 6,	7,	8,	8	8	8	10
Mt. Vernon,	7	....	3,	5,	8,	8	6	6	7
Nan,	39	....	10,	14,	8,	4	9	10	9
No. 1 H. See,	22	....	3,	5,	8,	6	7	4	5
No. 2 P. See,	23	....	7,	5,	8,	7	6	6	9
Ohio Centernial,	30	....	6,	12.	10,	8	8	6	10
Parker Earle,	34	....	7,	11.	10,	8	10	3	5
Perkin's, No 1,	44	....	9,	12,	12,	10	4	5	7

Quality,	53	....		14,	14,	8,	2	5	7	3
See No. 3,	46	....		12,	12,	10,	10	5	4	7
See No. 4,	47	....		10,	14,	9,	10	5	5	6
See No. 5,	48	....		9,	9.	8,	10	7	6	7
Shuster's Gem,	5	P	Apr.	29,	5,	8,	7	4	8	10
Smeltzer's Early,	28	....	May	2,	5,	8,	4	7	7	10
Steven's,	37	....		8,	5,	8,	5	8	4	5
Townsend,	29	....		11,	12,	10,	7	6	3	7
Van Dieman,	12	....		1,	5,	8,	6	4	5	7
Warfield.	36	P		6,	9,	8,	10	9	5	9
West Lawn,	26	P		3,	5,	8,	8	7	5	9
Wilson,	9	....		9,	9,	8,	5	8	3	7

Strawberries are usually planted and cultivated in the matted row in Pennsylvania, and in general this is the most profitable system.

Up to the time of planting this bed, it had been the system followed on the Station grounds, but the increasing demand for larger berries than have been grown by it, caused a trial of the hill system to be made by the side of the mat system in order to see what effect the former would have on the size, quality and yield of the fruit in comparison with the latter.

With this purpose in view, one-half of each variety was allowed to mat, while in the other half all runners were pinched off as they appeared. In all other respects the same treatment was given both systems.

In the following tables it will be seen that in the case of a little more than half the varieties grown by the two systems, the average size of the berries ranges from .15 grammes to 3.86 grammes higher in the hills than in the mat, while on the other hand the average of a number of the other varieties was greater in the mat than in the hills. But the hill system produced berries of much more uniformity of size and that were finer flavored and more highly colored.

As a rule, the fruit began to ripen from one to six days earlier and the plants remained in bearing from one to four days longer in the mat than in the hill system.

The following tables show the results of the trial of the two systems.

Table Showing Fruiting Season Strawberries, with Yield of 30 feet in Matted Row and an Equal Length of Row in Hill Culture, and Average Weight of Berries by Each System, all Weights in Grammes.

Varieties.		Plot No.	First ripe.	Last ripe.	Whole season's crop, in grammes.	Average weight of berries, in grammes.
Adam's Favorite, mat,		54	June 10,	July 12,	10,436	8.33
Banquet,	Mat,	14	3,	9,	8,370	3.26
	Hill,		7,	8,	3,615	3.53
Beebe,	Mat,	16	9,	8,	3,425	5.29
	Hill,		14,	10,	2,790	6.67
Boynton,	Mat,	27	5,	10,	10,265	3.58
	Hill,		5,	10,	5,230	4.95
Brandywine,	Mat,	24	12,	10,	7,805	6.01
	Hill,		14,	10,	4,240	5.78
Bubach,	Mat,	13	5,	5,	8,015	4.46
	Hill,		2,	8,	4.670	3.29
Carrie, mat,		55	16,	8,	....	10.00
Champion, mat,		50	12,	8,	5,813	9.76
Chas. Downing,	Mat,	2	3,	8,	3,225	2.41
	Hill,		7,	8,	2,245	3.09
Crawford,	Mat,	31	9,	9,	9,140	5.27
	Hill,		5,	8,	5,995	5.96
Crescent,	Mat,	3	11,	8,	10,570	3.54
	Hill,		7,	9,	6,680	6.15
Cumberland,	Mat,	8	5,	8,	7,275	4.41
	Hill,		9,	5,	2,440	5.57
Darling, mat,		57	....	....	....	....
Dayton,	Mat,	42	11,	5,	5,880	5.15
	Hill,		7,	2,	3,835	5.49
Ella, mat,		56	....	....	....	....
Enhance,	Mat,	35	14,	10,	8,040	6.74
	Hill,		10,	9,	3,270	6.25
E. P. Roe,	Mat,	26	5,	8,	6,535	7.95
	Hill,		7,	8,	2,810	4.66
Eureka,	Mat,	18	10,	8,	7,860	6.51
	Hill,		16,	10,	3,720	3.07

Varieties.		Plot No.	First ripe.	Last ripe.	Whole season's crop, in grammes.	Average weight of berries, in grammes.
Farnsworth,	Mat,	38	3,	8,	3,910	3.15
	Hill,		5,	8,	5,135	3.30
Gandy,	Mat,	17	16,	9,	5.610	6.14
	Hill,		18,	12,	2,365	10.00
Gov. Hoard,	Mat,	11	12,	10,	5,585	4.00
	Hill,		7,	5,	2,615	5.58
Greenville,	Mat,	4	9,	8,	7,645	5.06
	Hill,		14,	5,	5,250	3.24
Harrison, mat,		58	....	....	....	....
Hay's Prolific, mat,		49	10,	9,	2,960	6.06
Haverland,	Mat,	33	12,	8,	7,895	5.32
	Hill,		7,	8,	6,030	4.88
Henderson,	Mat,	32	7,	8,	10,620	3.75
	Hill,		11,	10,	7,670	2.80
Hull's No. 3, mat,		51	16,	8,	3,870	8.75
H. W. Beecher,	Mat,	43	14,	5,	4,805	9.02
	Hill,		17,	8,	1,230	10.00
Iowa Beauty, mat,		41	10,	8,	8,350	9.12
Kentucky,	Mat,	10	12,	8,	4,155	3.54
	Hill,		16,	10,	3,005	4.64
Leader,	Mat,	19	7,	8,	8,040	6.22
	Hill,		9,	9,	2,355	4.81
Luther,	Mat,	21	3,	5,	9,825	2.53
	Hill,		5,	8,	6,045	2.37
Maida, No. 11,860, mat,		52	14,	10,	5,625	....
Margaret, mat,		45	9,	8,	2,330	7.16
Mary, mat,		40	10,	10,	12,595	12.98
Meek's Early,	Mat,	6	May 31,	June 26,	2,155	2.50
	Hill,		June 1,	24,	1,575	1.84
Michel's Early,	Mat,	15	5,	July 1,	7,965	2.37
	Hill,		5,	June 29,	4,050	3.00
Monarch,	Mat,	1	5,	July 8,	7,360	3.55
	Hill,		7,	8,	3,330	3.39
Mt. Joy,	Mat,	20	7,	8,	8,615	5.76
	Hill,		12,	8,	4,040	6.92
Mt. Vernon,	Mat,	7	5,	8,	8,575	7.34
	Hill,		7,	8,	2,965	6.23
Nan,	Mat,	39	14,	5,	5,375	7.50
	Hill,		17,	8,	3,775	6.67
No. 1, H. See,	Mat,	22	5,	8,	6,850	2.85
	Hill,		7,	8,	3,850	2.09
No. 2 P. See,	Mat,	23	5,	8,	7,740	4.43
	Hill,		7,	8,	5,270	3.21
Ohio Centennial,	Mat,	30	12,	8,	8,775	6.45
	Hill,		15,	10,	2,980	7.53
Parker Earle,	Mat,	34	11,	9,	9,095	5.05
	Hill,		16,	10,	4,095	5.76
Perkin's No. 1, mat,		44	12,	12,	10,975	9.06
Quality, mat,		53	14,	8,	2,320	7.79
See, No. 3, mat,		46	12,	10,	11,667	6.57
See, No. 4, mat,		47	14,	9,	12,225	7.01
See, No. 5,		48	9,	8,	10,992	5.15
Shuster's Gem,	Mat,	5	5,	8,	8,420	3.16
	Hill,		5,	8,	5,595	4.74
Smeltzer's Early,	Mat,	28	5,	8,	5,435	2.66
	Hill,		9,	8,	3,110	3.96
Stevens,	Mat,	37	5,	8,	5,735	3.05
	Hill,		5,	5,	3,155	3.02
Townsend,	Mat,	29	12,	10,	8,015	6.13
	Hill,		12,	8,	3,295	5.83
Van Dieman,	Mat,	12	5,	8,	7,460	2.93
	Hill,		9,	8,	3,745	3.31
Warfield,	Mat,	36	9,	8,	10,780	3.95
	Hill,		14,	8,	7,400	5.14
West Lawn,	Mat,	25	5,	8,	9,345	5.12
	Hill,		7,	8,	4,605	4.77
Wilson,	Mat,	9	9,	8,	6,340	2.86
	Hill,		11,	5,	4,795	3.22

The following list contains such varieties as are deserving of special mention, and new varieties of which little or no report has been made:

Adam's Favorite. This variety was received from Solomon Adams, Tamaqua, Schuylkill county, Pa., in the spring of 1896. It is a pistillate variety of vigorous growth, matting freely and which is very little affected by leaf-blight. Berry is conical, blunt at the apex, about as long as broad, firm and acid and of large size. Yield is large. Grown entirely in mat.

Boynton. Another pistillate variety, bearing a heavy crop. Fruit ripened among the earliest and continued in bearing for five weeks. Berries are medium to large in size, very sweet, bright red in color and soft. Good for home use. This variety showed a difference of .27 grammes in favor of the hill system.

Carrie. Received from Thompson's Sons, Rio Vista, Va., in the spring of this year. Plants have shown good, vigorous growth, matting quite freely. Fruit is large to very large in size, ripens late, is bright red in color, elongated, having a smooth neck under the calyx. Flesh, firm. Not allowed to fruit generally this year. Grown entirely in mat.

Champion. Received from David Strouse, Royersford, Pa., in the spring of 1895. Grown entirely in mat so far. This variety mats quite freely, is vigorous and quite free from leaf-blight. Berries, large to very large, round conical, dark red, seeds few, flesh soft and sub-acid. Size of yield, medium.

Gandy. A vigorous growing, late variety, bearing large to very large berries, but small in yield. The difference in the size of berries grown by the two systems was very marked in the case of this variety. The average weight of the berries grown by the mat system was 6.14 grammes, while the average of those grown in hills was 10.00 grammes, nearly 4 grammes heavier.

Harrison. Received from George W. Adams, Tamaqua, Pa., in the spring of 1897. This variety has been very free in matting, very vigorous in growth and quite free from leaf-blight so far. Not allowed to fruit in order to allow the plants to become well established for next year.

Hay's Prolific. Received from Rodgers' Nursey Company, Moorestown, N. J., in the spring of 1896. This variety is vigorous, mats quite freely and resists leaf-blight well. Fruit ripens a little late, and in size is from medium to large, but in yield is poor. This being but the first year, it will be given a longer trial. Grown in mat.

Henderson. This variety is one of the best in point of yield, but the average size of the berries is rather small.

Hull's No. 3. Received in the fall of 1895 from E. J. Hull, Olyphant, Pa. This variety is a little over medium in point of runners and vigor and is badly affected by leaf-blight. Fruit ripened late and was of large size, but poor in quantity. It might be expected to give better results in the new bed.

Iowa Beauty. A perfect, flowered variety, of vigorous habit. Berries large to very large, broadly conical, red, few seeds, large calyx and very sweet. Flesh soft even before fully ripe. Good for home use.

Maida, No. 11,860. Received through the Div. of Pom., Washington, D. C., from William King, of Carlin, Va. Plants are very vigorous, but yield was not satisfactory this year. Will be given a further trial. Grown entirely in mat. This variety would seem to be well adapted to hill culture, owing to a tendency which it has to grow in that way.

Margaret. Received from M. Crawford, Cuyahoga county, O., in 1895. A perfect, flowered variety of very vigorous growth. Berries all large to very large, dark red, few seeds, large calyx, flesh solid and mild. Very poor in yield this year, but might be expected to give better results in the new bed.

Mary. A remarkable berry. It showed the highest average size of fruit of all the varieties grown, and all the berries produced were very large. The yield was also the heaviest of all the varieties. The berry is flat at the apex and in longitudinal section is almost square. It has a good color, few seeds, deeply bedded and the flesh is firm and acid. Forty-seven berries weighed 610 grammes. Plants are amongst, if not the most, vigorous of all the varieties and hold the same position in regard to runners. Up to this time it has been grown entirely in mat.

Meek's Early. This is, indeed an early variety and is fairly strong in growth. The fruit ripens several days before any other variety and for this reason is grown by a good many strawberry growers. It is very poor in size and yield after the first few pickings. This variety showed a difference in average size of .66 grammes in favor of the mat system.

Perkins No. 1. Another very large berry, received from Jackson & Perkins, Newark, N. J., in 1894. Berries range in size from large to very large, are almost spherical in shape, with few seeds, which are deep set in the flesh and which drop out as the berry becomes ripe. The color is bright red and the flavor slightly acid. This variety ranks with the best in point of yield, which is of the most importance, and also ranks high in average size of the berries. Grown in mat.

Quality. Received from M. Crawford, Cuyahoga county, O., in 1896. Plants are vigorous, but the yield is very poor, ranking only two in a scale of from one to ten. Fruit ripens late. A further trial will be given it.

See, No. 3. Received from H. S. and A. J. See, Geneva, Pa., in 1895. Berries large to very large, roundly conical, with sometimes a broad apex. It has a good dark red color, is slightly acid in taste and the flesh is solid. Fruit is a little late in ripening. This variety was among the heaviest in yield and also had a very good average weight. It mats with moderate freedom.

See, No. 4. Received as preceding, in 1895. Berries large to very large, almost globular in form, with numerous seeds. Fruit ripens a little later and the season closes a little earlier than the preceding, but the crop is heavier and the average size is larger. It also mats more freely than See, No. 3.

See, No. 5. Received as preceding, in 1895. Berries large to very large, having a good strawberry form, broadly conical, a good color, few seeds and solid, acid flesh. This is another variety with a large yield, although it does not come up to the two preceding varieties in either yield or average. Mats more freely than either.

Townsend. A fairly vigorous, late variety, sending out but few runners. Berries all from large to very large, dark red, many seeds and flesh red and firm. A good variety in point of yield also.

Warfield. A good standard variety, bearing a heavy crop.

Parker Earle. A late variety, with a good record here. Berries, long conical in shape, and from medium to large in size, have a good color, and are firm and sweet. Yield is heavy for almost its entire season, which is between three and four weeks. This variety showed a difference of .71 grams in favor of the hill system.

Shuster's Gem. This variety has been a small fruited one, ranging from small to medium, but hill culture has made a decided improvement in both the color and size of the berries. The average size was raised over 1.50 grammes, while the yield for the hill system was fully two-thirds the size of that of the mat.

Van Dieman. A strong growing variety, bearing a large crop of medium-sized berries. The yield of the hills was about half as large as that of the mat, while a comparison of the averages shows a difference of .38 grammes in favor of the hill system.

West Lawn. A strong growing variety, with a good yield to its credit. Berries, medium sized, with good color and flavor. The mat produced the larger sized berries.

Ohio Centennial. A good, vigorous variety, bearing a good crop of medium to large berries. Larger in the mat than in hills.

No. 1, H. See. Received from H. S. & A. J. See, Geneva, Pa., in 1894. A very small fruited variety. Berries small, round, soft and sweet. Plants send out but few runners, are not very vigorous and rust badly. Discarded this fall.

No. 2, P. See. Received as preceding in 1894. Berries, medium sized, conical, bright red and sub-acid. Twice as large in yield, size of berries and vigor as preceding.

RASPBERRIES.

The system of pruning and training followed here is that known as summer pinching. This is the system usually followed by growers on a large scale.

This method of pruning is simply the pinching off of the terminal bud as soon as the young shoot or cane has reached the desired height, which is from 18 inches to 3½ feet, according to the idea of the grower. Pinching back in this way tends to strengthen the canes and in some cases it was found unnecessary to use stakes, but in the case of a majority of the varieties it was found that the plants required tying up to allow of easy cultivation. Plants here have been kept at a height of three feet and in the case of one or two varieties, at four feet. In all probability had they been kept lower they would have required no stakes at all.

This practice of pinching checks the upward growth of the cane and causes it to send out lateral branches, at the same time causing the wood already formed to become fully matured as a result of which the plants stand the winters well. Another great advantage which this system has over fall pruning is that it does not waste the strength of the plants in forming wood, which has to be cut off in the fall or winter.

The following table gives the results of the season of 1897:

Variety.	Plot No.	Color.	First flower.	First ripe.	Last ripe.	Yield of 6 plants, in grammes.	Average weight, in grammes.	Rust.	Vigor.
Ada,	22	Black,	June 1,	July 5,	Aug. 2,	3,913	.86	2	7
All Summer,	28	Red,	May 31,	5,	10,	4,335	1.91	2	7
Brackett's No. 101,	25	Black,	26,	June 30,	2,	4,950	1.24	5	8
Brandywine,	2	Red,	31,	30,	6,	6,048	1.16	1	7
Brinkle Orange,	18	Yellow,	27,	30,	4,	4,314	1.17	4	5
Curcline,	5	Yellow,	28,	29,	7,	9,708	1.09	5	8
Columbian,	20	Purple.	June 8,	July 8,	2,	10,995	1.67	4	9
Cuthbert,	6	Red,	1,	June 28,	7,	12,588	1.63	5	8
Fadely,	16	Black,	May 25,	30,	July 31,	4,098	.99	5	7
Golden Queen,	17	Yellow,	31,	July 3,	Aug. 4,	8,425	1.55	7	7
Gregg,	14	Black,	31,	6,	July 29,	5,400	1.03	3	6
Hansell,	4	Red,	28,	June 28,	Aug. 7,	7,900	1.46	2	7
Herstine,	9	Red,	28,	30,	2,	2,118	1.30	8	8
Hiddle's No. 500,	8	Black,	24,	28,	2,	7,225	.87	4	7
Kansas,	7	Red,	31,	28,	2,	8,663	1.41	4	7
Loganberry,	19	Red,	29,	30,	July 29,	420	5.00	8	8
Lovett's,	27	Black,	24,	28,	19,	2,210	.74	1	7
Mammoth Cluster,	13	Black,	24,	28,	24,	5,598	.91	1	7
Marlboro,	3	Red,	31,	28,	Aug. 2,	5,808	1.32	6	5
Ohio,	15	Black,	29,	July 4,	July 29,	10,915	.70	2	7
Older,	21	Black,	24,	June 30,	30,	8,796	1.26	5	7
Philadelphia,	1	Red,	28,	28,	Aug. 4,	5,328	1.21	1	7
Rancocas,	11	Red,	25,	27,	2,	6,660	.97	5	7
Shaffer's Colossal,	12	Purple,	June 8,	July 4,	4,	13,220	1.70	2	10
Smith's Prolific,	24	Black,	May 25,	June 29,	July 22,	2,893	.99	3	7
Thompson,	23	Red,	29,	26,	Aug. 2.	2,658	1.30	1	7
Turner,	10	Red,	28,	30,	July 31,	6,355	1.68	2	8
Wineberry,	26	Orange,	June 10,	July 15,	Aug. 10,	4,240	.94	2	9

The following list is made up of some of the most noteworthy varieties, together with new varieties:

All Summer. A vigorous growing red variety, which is said to remain in bearing "all summer," but which has turned out to be but a few days later than the other varieties here. Many berries are quite large, but the average is small and the yield poor, so far.

Columbian. A very large growing variety, bearing large, purple fruit, and which has been doing nicely here. But last winter all of the raspberries here suffered more than usual, and this variety more than any. Of six plants, but two were growing in the spring, one of those being severely injured. It very nearly equals Cuthbert in yield.

Cuthbert. A good standard variety, which is too well known to need description.

Fadely. A vigorous growing black cap variety, which has a small yield of small berries. They break up badly.

Huddles, No. 500. Another black variety with a medium-sized yield and small average sized berry. Plants vigorous and quite free from rust.

Loganberry. Two plants of this variety were received in the fall of 1896, kept over winter in pots and planted out this spring. They were allowed to bear a few berries. Berries are of large size, dark red in color and have a good flavor. This variety is sometimes called the Raspberry-Blackberry. It resembles the raspberry in habit and color of the fruit, and the blackberry in the shape and size of the leaves and berry. Like the blackberry, the receptacle comes off with the fruit.

Ohio. A vigorous growing variety, very free from rust. It has a small, average-sized berry, but a large yield.

Shaffer's Colossal. Certainly a "colossal" variety. Plants are very vigorous and free from rust. Bushes about five feet in height and if allowed to, would probably reach six or eight feet. Fruit ripens late and remains in bearing with the latest. Berries, large, purple in color and has a fine flavor. Ranks with the best in average size of the berry and has the largest yield of any variety grown here, to its credit.

BLACKBERRIES.

The table below contains the general notes on the varieties here, together with the weight of the crop of six plants and the average weight of berries.

Varieties.	Plot No.	First flower.	First ripe.	Last ripe.	Yield of 6 plants, in grms.	Average weight, in grms.	Rust, 1 to 10.	Vigor, 1 to 10.
Child's Tree,	20	June 3,	July 19,	Aug. 29,	10,815	2.60	7	9
Clark,	22	....	....	....	....	....	....	....
Crystal White,	10	2,	19,	29,	3,318	1.83	4	7
Dorchester,	9	May 28,	15,	27,	3,218	1.30	5	8
Early Cluster,	6	June 3,	21,	27,	6,174	2.31	6	7
Early Harvest,	8	2,	6,	27,	9,552	1.95	6	6
Early King,	11	May 29,	17,	27,	6,528	2.28	4	6
Eldorado,	4	27	16,	27,	7,518	2.93	5	8
Erie,	19,	31,	19,	27,	8,600	3.65	6	7
Huddle's, No. 300,	13	June 2,	19,	23,	2,108	1.67	7	5
Kittatiny,	1	May 28,	16,	29,	8,820	3.53	6	9
Lawton,	7	25,	21,	25,	10,400	1.35	6	7
Lovett's Best,	5	June 3,	23,	25,	9,400	2.85	5	7
Lucretia Dewberry,	3	May 25,	3,	18,	9,150	3.13	9	8
Luther,	17	June 3,	16,	27,	6,108	2.68	8	7
Maxwell's Early,	18	4,	16,	4,	3,390	....	4	4
Rathbun,	16	May 31,	17,	27,	4,085	1.08	8	7
Snyder,	2	25,	16,	27,	5,832	1.95	4	7
Thompson's Early Mammoth,	14	31,	16,	23,	3,705	1.48	8	5
Wilson's Early,	12	26,	15,	27,	8,315	2.54	5	7
Wilson, Jr.,	21	28,	16,	6,	560	....	5	7

Child's Tree. This variety is a very vigorous growing one, and bore the heaviest crop of all this year. It is a late variety. Berries, large to very large, purplish black, firm and sweet.

Early Harvest. A very early variety, bearing a heavy crop. Berries, medium in size and very firm.

Eldorado. Received from E. M. Benchly, Greenville, O., in 1890. A very vigorous variety, little affected by rust and yields a heavy crop. Berries, from large to very large in size and very sweet.

Erie. Another very vigorous variety and bore a somewhat larger crop than the preceding. In the average size of berries this variety leads all the varieties grown here. Kittatiny coming second with Lucretia Dewberry third.

Kittatiny. A well known variety of very vigorous growth, bearing a heavy crop of berries of very large size.

Lawton. This variety bore the second largest crop this year. The average, however, was very low. Plants are very strong and moderately free from rust.

Lovett's Best. Received from Lovett Co., N. J. A vigorous variety, which bore a good crop of good average-sized berries.

Luther. Received from R. D. Luther, Freedonia, N. Y., in 1893. A strong growing variety, which has been badly affected by rust here. It bears a medium-sized crop of large berries, but has done better in former years than in this.

Maxwell's Eearly. Received from A. C. Maxwell, Chaunte, Kas., in 1892. This variety is evidently too tender for this locality. It is very weak in growth, bears a very small crop and has a very short period of bearing.

CURRANTS.

This year the currant worm (Nematus ventricosus) appeared in large numbers a little earlier than usual and in spite of repeated applications of hellebore, did a great deal of damage. No arsenite was used for fear of poisoning the fruit, which, by this time, was well formed.

About this time a "kerosene spray pump," to be attached to a bucket was received from the Deming Company, of Salem, O., and was used on both the currants and gooseberry bushes with splendid results. At a strength of two-tenths, all the worms were killed and not a leaf injured. Have used this sprayed on various other plants for caterpillars, web-worms, scale and lice, and have not seen any machine equal to it.

In other cases, as in this, the best way is to prevent a pest rather than to depend upon remedying it after it has become established.

Varieties and Color.	Plot No.	First flower.	First ripe.	Last ripe.	Yield of 3 plants in grams.
Black Champion, black, ...	9	May 1,	June 26,	July 26,	2,566
Black Naples black, ...	5	3,	26,	26,	2,805
Crandall's, black, ...	12	Apr. 28,	30,	26,	....
Cherry, red, ...	6	27,	17,	7,	8,100
Fay's Prolific, red, ...	10	27,	24,	14,	9,480
Versailles, red, ...	3	27,	18,	14,	13,585
Lee's Prolific, black, ...	8	May 3,	26,	26,	3.210
Red Dutch, red, ...	4	Apr. 26,	17,	14,	13,691
Red Grape, red, ...	11	27,	17,	14,	21.443
Storrs & Harrison, red, ...	1	28,	21,	14,	9,780
Victoria, red, ...	2	28,	20,	14,	15,008
White Grape, white, ...	7	28,	21,	16,	6,275

Cherry. A good vigorous variety, bearing very fine large red berries, in medium sized clusters, but only a little over a medium sized crop.

Fays Prolific. A much weaker growing variety than the preceding but bore a larger crop of berries of about the same size and quality.

Red Grape. This is the banner variety of currants this year in point of yield. It is only a moderately strong growing variety.

Victoria. This variety is a good, vigorous growing one, quite free from rust, and bore the second largest crop this year.

Storr's & Harrison. A variety received from Storrs & Harrison, Painesville, O., and planted in 1893. It makes a very vigorous growth, is quite free from rust and bears a medium-sized crop of medium-sized berries.

GOOSEBERRIES.

What has been said in regard to the currant, relating to the currant worm, is also applicable to this fruit.

The following table gives the general notes on all the varieties grown, together with the yield of six plants, in grammes:

Varieties.	Plot No.	First flower.	First ripe.	Last ripe.	Yield of 6 plants.
Chautauqua, ...	7	Apr. 28,	July 5,	July 16,	1.830
Downing, ...	2	27,	June 30,	15,	23.944
Golden Prolific, ...	6	May 3,	July 8,	....	....
Houghton, ...	4	Apr. 28,	1,	15,	44.034
Industry, ...	3	28,	3,	....	....
Pearl, ...	9	27,	3,	16,	7.088
Roesch, ...	8	27,	2,	16,	12.210
Smith, ...	1	27,	June 29,	6,	4.059
Triumph, ...	5	27,	July 3,	16,	12.630

Golden Prolific and Industry are both large fruited varieties, but the yield so far has been almost nothing. In the notes this year, the former had "only one berry," while the latter had "too few to pick."

Houghton, Downing, Triumph and Roesch were the four leading varieties in point of yield this year, in the order named. The first two are small-fruited varieties, while the last two are quite large.

THE SUGAR BEET IN PENNSYLVANIA.

BY HENRY PRENTISS ARMSBY.

The United States is one of the great sugar-consuming countries of the world.* The amount of sugar annually used in the United States exceeds by 500,000 tons that of any European country, and the per capita consumption is second only to that of England, the average consumption per head being 62.6 pounds, as against 86.1 pounds in the latter country. The total annual consumption of sugar is nearly or quite two million tons. Of this amount about 85 per cent. is imported from foreign countries and its actual value at ports of entry, not including customs duties, averaged for the years 1891-5 over one hundred million dollars. Within the past two years there has been a notable revival of interest in the question whether this country cannot produce its own sugar and particular attention has been directed to the sugar beet as a source of sugar. From very small beginnings early in this century (the first beet sugar factory, founded in 1805, having had a capacity of 525 tons of beets for the season) this plant has come to outrank the sugar cane as a source of sugar. In 1896-7 the world's product of sugar was approximately as follows:

From sugar cane, ...	2,747,500 tons.
From the sugar beet, ...	4,960,000 tons.
	7,707,500 tons.

In other words, the sugar beet is producing about 64 per cent. of the world's sugar supply, or for every pound of sugar produced from sugar cane over 1.8 pounds are produced from the sugar beet. It is a noteworthy fact that during the Cuban war the sugar exports from that country have fallen off from about one million tons to less than one-tenth that amount, yet there has been no appreciable shortage in the world's supply of sugar, the sugar beet having been able to make good the diminished production of sugar from the sugar cane.

Very nearly all this enormous amount of beet sugar is produced in the countries of continental Europe. Of our own domestic production of sugar, amounting to about 300,000 tons per annum, 84 per cent. is produced from the sugar cane, 14 per cent, from the sugar beet and 2 per cent. from sorghum, maple and miscellaneous sources.

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*The statistics in the following pages are chiefly those given by Wiley in Farmers' Bulletin No. 52 of the U. S. Department of Agriculture. For convenience only round numbers are given here

Beet sugar has been made in this country in small amounts since 1830, but not until 1889 did the product exceed 2,000 tons per annum. Since then, there has been a steady growth in the production, the estimates for 1896 being in the neighborhood of 40,000 tons, the product of seven factories, three situated in California, two in Nebraska, one in New Mexico and one in Utah.

NATURE OF THE PROBLEM.

In considering the question of the domestic production of sugar from the beet, a sharp distinction must be made between the two parts of the question. These are, first, the production of the beets and second, the manufacture of sugar from them. The second portion of the problem has been very thoroughly worked out in European countries and is not a question at present needing investigation in this country. The technology of sugar manufacture has been perfected by years of study and experience, and is now very thoroughly understood. It is not an industry which can be carried on on the small scale by the farmer himself, or even in a small factory. The most reliable estimates place the minimum size of a successful beet sugar factory at a capacity of 300 tons of beets per day, and the cost of such a factory is estimated at not less than $200,000. The season during which sugar can be manufactured is comparatively short, being limited by the length of time during which the beets can be preserved, and to secure an adequate return upon the capital invested requires that the factory shall be run to its full capacity during the season, and that the best technical skill shall be employed to direct its operations. All hope on the part of farmers that they can manufacture beet sugar with simple and inexpensive apparatus should be given up once for all. The question for us now is whether we can raise good sugar beets in sufficient quantity to supply a factory and at a cost which will leave an adequate profit. The farmer should confine his attention strictly to this side of the question. When he can and will produce the beets, capital will be forthcoming to manufacture the sugar, as has been amply demonstrated in other states.

OBJECT OF EXPERIMENTS.

The object of the experiments here reported was to test the adaptability of the soil and climate of Pennsylvania to the culture of the sugar beet and thus to help the farmer to decide the question of the practicability of its culture.

Experience has shown that the sugar beet reaches its highest development in north temperate latitudes. So far as temperature is concerned, a belt extending about one hundred miles either side of the isotherm of 70 degrees for the months of June, July and August is generally regarded as the region best adapted for its cultivation. This "sugar-beet belt" includes the larger part of Pennsylvania. Many other conditions, however, particularly soil and rainfall or other water supply, materially affect the question. The winter temperature also affects the length of the working season by limiting the length of time during which the beets can be preserved. Whether any given locality is adapted to raising sugar beets can only be told with certainty by actual trial. Such trial, however, cannot successfully be made by the farmer alone. The results are of value only when, in the first place, true sugar beet seed has been used and when, in the second place, the resulting beets are analyzed. In order to secure these two conditions, the Station, at the suggestion of the United States Department of Agriculture, entered into co-operative experiments with that Department upon this subject.

PLAN OF EXPERIMENTS.

Imported sugar beet seed of the Kleinwanzleben variety was supplied by the United States Department of Agriculture and distributed by the Station to such farmers in various portions of the State as were willing to undertake to grow the beets in accordance with directions and send samples to the Station for analysis. With the seed were sent careful instructions as to culture, harvesting and sampling, and franked tags were supplied by the Department for the free mailing of samples to the Station for analysis. Of the forty farmers to whom seed was thus sent, only fifteen forwarded samples to the Station for analysis, with more or less complete data as to cultivation, yield, etc. Fortunately, several of the fifteen sent more than one sample, and two in particular interested several of their neighbors in the subject, so that in all fifty-two samples were secured.

WHAT IS A GOOD SUGAR BEET?

Since all sugar beets contain more or less sugar it is necessary, in order to form a judgment as to the meaning of the results obtained, to know what percentage of sugar and what other properties are necessary to render a beet suitable for the manufacture of sugar. In general, the requirements are three.

1. Size. If the beets are too small, the yield per acre is likely to be light and the profits to the grower little or nothing. On the other hand, if the beets are too large, they are apt to be poor in sugar. General experience has fixed upon the weight of about one to one and one-thirds pounds as the size best suited to secure the interests of both farmer and manufacturer.

2. Sugar content. While, as stated above, all sugar beets contain some sugar, it has not usually been found practicable to manufacture sugar commercially from beets containing less than 12 per cent.

3. Purity. By the purity of a sugar beet is meant the proportion

which the sugar bears to other soluble ingredients. This is of importance because these other soluble ingredients prevent a portion of the sugar from crystallizing and, therefore, diminish the yield. The purity is expressed by the percentage of sugar compared with that of total soluble matter. Thus, if the juice of a sugar beet contains 14 per cent. of total solid matter in solution and 12 per cent. of sugar, the co-efficient of purity is 12 divided by 14, or 85.72 per cent. The lowest percentage of purity admissible in the beets to be used for manufacturing sugar is usually stated at 80 per cent., although this depends a little upon the absolute richness in sugar.

RESULTS IN DETAIL.

The following table includes the results upon sixty-nine samples. These include a number of samples grown in Pennsylvania but analyzed by the United States Department of Agriculture. We are indebted for the use of these results to the courtesy of Dr. H. W. Wiley, Chief of the Division of Chemistry. They are distinguished in the the table by being printed in italics. The samples from Cumberland and Franklin counties were all sent to the Station by Mr. Frank C. Bosler, of Carlisle, to whose active interest in the subject we are indebted for the large number of trials made in these two counties. The seed of Vilmorins Improved was procured by Mr. Bosler at his own expense and in addition he had tests made of two other varieties. The results of these latter, however, were so much inferior that they are not included in this table, but are presented by themselves. The Station is likewise indebted to Hon. John H. Landis, of Millersville, for the prosecution of a number of experiments in Lancaster county.

No.	Name.	Postoffice.	Variety.	Soil and Culture.
	ALLEGHENY COUNTY.			
1	*Arthur Kirk,*	*Sharpsburg.*		
2	*Arthur Kirk,*	*Sharpsburg.*		
3	*Andrew Geimer,*	*Dorseyville,*		*Clay.*
4	*Arthur Kirk,*	*Sharpsburg,*		
5	" "	*Sharpsburg.*		
6	" "	*Sharpsburg,*		*Loam.*
7	" "	*Sharpsburg.*		
8	" "	*Sharpsburg.*		
9	*Andrew Geimer,*	*Dorseytown,*		*Clay.*
	BRADFORD COUNTY.			
10	**J. R. Vaunoy,**	**East Troy,**	**Klein Wanzlebener,**	**Clay loam; plowed in fall of 1896; beets cultivated three times; sample wilted.**
11	**Louis Piollet,**	**Wysox,**	**Klein Wanzlebener,**	**Sandy loam; cultivated six times.**
12	**Louis Piollet,**	**Wysox,**	**Klein Wanzlebener,**	**Sandy loam; cultivated six times; sample wilted.**
	BUCKS COUNTY.			
13	**R. P. Lovett, Jr.,**	**Fallsington,**	**Klein Wanzlebener,**	**Fine brown loam.**
	CENTRE COUNTY.			
14	**Experiment Station,**	**State College,**	**Klein Wanzlebener,**	**Clay; beets cultivated five times.**
15	**Experiment Station,**	**State College,**	**Klein Wanzlebener,**	**Clay; beets cultivated five times.**
16	**Experiment Station,**	**State College,**	**Klein Wanzlebener,**	**Clay; beets cultivated five times.**
17	**Experiment Station,**	**State College,**	**Wohawka,**	**Clay loam; beets cultivated enough to keep weeds destroyed and ground loose.**
	CHESTER COUNTY.			
18	**T. L. Passmore,**	**Chatham,**	**Klein Wanzlebener,**	**Clay loam; old garden for six years.**
19	**T. L. Passmore,**	**Chatham,**	**Klein Wanzlebener,**	**Clay loam; old garden for six years; sample wilted.**
	CLEARFIELD COUNTY.			
20	**J. B. Ferguson,**	**Lumber City,**	**Klein Wanzlebener,**	**Light sand loam; in cultivation for ninety-five years.**
21	**J. P. Watts,**	**Kerrmoor,**	**Klein Wanzlebener,**	**Slate soil; cleared in '89; very poor stand; no weights taken; sample much wilted.**
	COLUMBIA COUNTY.			
22	**A. P. Young,**	**Millville,**	**Klein Wanzlebener,**	**Thin clay slate; beets cultivated five times; sample wilted.**
23	**A. P. Young,**	**Millville,**	**Klein Wanzlebener,**	**Clay slate soil; beets cultivated five times; sample badly wilted.**
	CRAWFORD COUNTY.			
24	*A. L. Tucker,*	*Drakes Mills,*		*Sandy loam.*

No.	Name.	Postoffice.	Variety.	Soil and Culture.
	CUMBERLAND COUNTY.			
25	Frank C. Bosler,	Carlisle,	Klein Wanzlebener,	Heavy clay; cultivated for 50 years; beets cultivated eight times.
26	Frank C. Bosler,	Carlisle,	Klein Wanzlebener,	The same.
27	Geo. Shugars,	Carlisle,	Klein Wanzlebener,	Clay and limestone; sample wilted.
28	Geo. Shugars,	Carlisle,	Klein Wanzlebener,	The same.
29	D. Raudabaugh,	Carlisle,	Klein Wanzlebener,	Limestone and clay; beets cultivated twice and hoed three times.
30	D. Raudabaugh,	Carlisle,	Klein Wanzlebener,	The same.
31	John Rhodes,	Carlisle,	Klein Wanzlebener,	Wet, gravelly clay loam.
32	John Rhodes,	Carlisle,	Klein Wanzlebener,	The same.
33	—— Garman,	Carlisle,	Klein Wanzlebener,	Red clay, in cultivation many years; beets cultivated four times.
34	—— Garman,	Carlisle,	Klein Wanzlebener,	The same.
35	Frank C. Bosler,	Carlisle,	Vilmorin's Improved,	Same as No. 24.
36	Frank C. Bosler,	Carlisle,	Vilmorin's Improved,	Same as No. 24.
37	Wm. Stone,	Carlisle,	Vilmorin's Improved,	Decomposed slate rock; beets cultivated four times.
38	Wm. Stone,	Carlisle,	Vilmorin's Improved,	The same.
39	Vance McCormick,	Carlisle,	Vilmorin's Improved,	Loose gravel.
40	Vance McCormick,	Carlisle,	Vilmorin's Improved,	The same.
	ELK COUNTY.			
41	*H. R. Manett,*	*Cartwright,*		*Clay.*
42	*H. R. Manett,*	*Cartwright,*		*Clay.*
	FRANKLIN COUNTY.			
43	W. H. Stamey,	Fayetteville,	Vilmorin's Improved,	Sandy loam; in culture for 25 years.
44	W. H. Stamey,	Fayetteville,	Vilmorin's Improved,	The same.
45	Hon. Jas. W. Carson,	Mercersburg,	Vilmorin's Improved,	Sandy loam; beets cultivated three times.
46	Hon. Jas. W. Carson,	Mercersburg,	Vilmorin's Improved,	The same.
	LACKAWANNA COUNTY.			
47	J. L. Stone,	Waverly,	Klein Wanzlebener,	Stony loam, hard pan sub-soil; beets cultivated three times.
	LANCASTER COUNTY.			
48	Chas. E. Maule,	Christiana,	Klein Wanzlebener,	Sandy loam, clay sub-soil; beets cultivated four times.
49	Chas. E. Maule,	Christiana,	Klein Wanzlebener,	Sandy loam, clay sub-soil; beets cultivated four times.
50	John H. Landis,	Millersville,	Klein Wanzlebener,	Limestone soil; beets hoed every ten days.
51	S. N. Mumma,	Landisville,	Klein Wanzlebener,	Sandy limestone; in cultivation for 50 years.
52	John B. Eshleman,	Columbia,	Klein Wanzlebener,	Sandy loam; beets cultivated enough to keep weeds destroyed; sample wilted.
53	David E. Moyer,	Strasburg,	Klein Wanzlebener,	Flinty loam; in cultivation for 50 years.
54	F. B. Deitrich,	Millersville,	Klein Wanzlebener,	Sandy loam soil; beets cultivated twice.
55	John H. Landis,	Millersville,	Klein Wanzlebener,	Limestone soil; beets hoed every ten days.
56	Benj. K. Andrews,	New Providence,	Klein Wanzlebener,	Sand loam; beets cultivated three times; sample wilted.
57	A. H. Brubaker,	Rohrerstown,	Klein Wanzlebener,	Deep rich loam.

	LAWRENCE COUNTY.			
58	*Wm. A. Clark,*	*New Wilmington,*		*Clay.*
	LEBANON COUNTY.			
59	*Edward Schuratly,*	*Richland,*		*Limestone*
	McKEAN COUNTY.			
60	A. B. Armstrong,	Smethport,	Klein Wanzlebener.	
	MERCER COUNTY.			
61	J. F. Gilkey,	Wheeler,	Klein Wanzlebener,	Loose clay loam.
62	T. L. Philips,	Sheakleyville,	Klein Wanzlebener,	Clay; beets cultivated three times.
63	T. L. Philips,	Sheakleyville,	Klein Wanzlebener,	Clay; beets cultivated three times.
	PERRY COUNTY.			
64	*Silas Wright,*	*Reward*	*Klein Wanzlebener,*	*Red soil.*
65	*Silas Wright,*	*Reward,*	*Klein Wanzlebener,*	*Red soil.*
	WYOMING COUNTY			
66	Horace Seamens,	Factoryville,	Klein Wanzlebener,	Sandy loam; gravely sub-soil; beets cultivated six times.
	YORK COUNTY.			
67	J. S. Young & Co.,	Hanover,	Klein Wanzlebener,	Good quality of clay; beets cultivated four times.
68	J. S. Young & Co.,	Hanover,	Klein Wanzlebener,	Good quality of clay; beets cultivated four times.
69	*Wm. Hammill,*	*Stewartstown,*		*Dark Loam.*

No.	Name.	Distance apart of rows, inches.	Time of planting.	Time of harvesting.	Yield per acre, tons.	Average weight of one beet, lbs.	Average weight of sample beets, lbs.	Brix density.	Sugar in juice, per cent.	Sugar in beets, per cent.	Purity.
	ALLEGHENY COUNTY.										
1	*Arthur Kirk,*	....	....	....	....	....	*1.25*	....	*7.9*	*7.6*	
2	*Arthur Kirk,*	....	....	....	....	....	*0.94*	....	*14.4*	*13.7*	
3	*Andrew Grimer,*	....	*May 10,*	*Sept. 20,*	....	....	*0.63*	....	*12.7*	*12.1*	*74.3*
4	*Arthur Kirk,*	....	....	....	....	....	*1.06*	....	*7.5*		
5	*Arthur Kirk,*	....	....	....	....	....	*0.63*	....	*11.1*	*10.6*	*72.6*
6	*Arthur Kirk,*	....	....	*Oct. 8,*	....	....	*1.19*	....	*16.7*	*16.0*	*74.9*
7	*Arthur Kirk,*	....	....	....	....	....	*1.38*	....	*17.2*	*16.4*	*74.7*
8	*Arthur Kirk,*	....	....	....	....	....	*1.13*	....	*16.2*	*15.4*	*72.3*
9	*Andrew Grimer,*	....	*May 10,*	*Oct. 12,*	....	....	*1.50*	....	*13.1*	*12.5*	*74.9*
	Average	....	....	....	....	....	*1.07*	....	*12.9*	*13.0*	*74.0*
	BRADFORD COUNTY.										
10	J. R. Vaunoy, ...	36	May 20,	Nov. 9,	33.3	1.64	....	19.67	15.90	15.11	80.84
11	Louis Piollet, ...	30	May 28,	Oct. 10,	....	....	1.85	17.09	14.93	14.18	87.37
12	Louis Piollet, ...	30	May 28,	Nov. 10,	15.0	....	1.85	20.71	17.50	16.63	84.50
	Average, ...	....	....	....	....	....	1.85	19.15	16.11	15.30	84.13
	BUCKS COUNTY.										
13	R. P. Lovett, Jr., ...	36	May 29,	Dec. 7,	13.21	0.97	1.17	16.07	12.53	11.90	77.98
	CENTRE COUNTY.										
14	Experiment Station, ...	30	....	Sept. 10, ...	4.17	0.30	.44	20.63	16.28	15.47	78.92
15	Experiment Station, ...	30	....	Sept. 24, ...	7.22	0.72	1.15	16.07	12.65	12.02	78.70
16	Experiment Station, ...	30	....	Oct. 28, ...	7.57	0.52	1.10	17.20	14.15	13.44	82.27
17	Experiment Station, ...	36	....	Oct. 28, ...	3.22	0.23	0.76	14.90	12.30	11.63	82.55
	Average, ...	....	....	....	5.55	0.44	0.86	17.20	13.84	13.15	80.47
	CHESTER COUNTY.										
18	T. L. Passmore, ...	33	May 12,	Nov. 20,	19.1	1.57	1.22	15.57	11.25	10.69	72.24
19	T. L. Passmore, ...	33	May 12,	Nov. 20,	19.1	1.57	0.79	15.82	11.83	11.24	74.66
	Average, ...	....	....	....	19.1	1.57	1.00	15.70	11.54	10.97	73.51

	CLEARFIELD COUNTY										
20	J. B. Ferguson,	30	May 10,	Oct. 28,	11.7	1.03	...	21.97	17.54	16.66	79.9
21	J. P. Watts,	...	May 22,	Oct. 29,	...	...	.55	26.74	23.45	22.28	87.7
	Average,	...	...	...	11.7	1.03	.55	24.35	20.49	19.47	84.15
	COLUMBIA COUNTY.										
22	A. P. Young,	...	May 16,	Nov. 2,	...	0.67	1.51	18.66	12.13	11.52	65.00
23	A. P. Young,	...	May 16,	...	...	0.69	1.25	26.00	20.73	19.69	79.78
	Average,	...	...	...	...	0 68	1.38	22.33	16.43	15.61	73.58
	CRAWFORD COUNTY.										
24	*A. L. Tucker,*	...	*May 13,*	*Oct. 12,*	...	...	*1.38*	...	*12.9*	*12.3*	*78.7*
	CUMBERLAND COUNTY.										
25	Frank C. Bosler,	18	May 11,	Oct. 11,	8.71	0.42	0.71	14.90	10.43	9.90	69.80
26	Frank C. Bosler,	18	May 11,	Nov. 1,	10.12	0.57	0.78	16.61	13.60	12.92	81.84
27	Geo. Shugars,	...	May 19,	Oct. 12,	...	0.50	...	20.20	16.82	15.98	83.20
28	Geo. Shugars,	...	May 19,	Nov. 2,	...	0.50	0.49	16.99	14.45	13.73	85.06
29	D. Raudabaugh,	37	May 17,	Oct. 12,	11.32	1.18	...	19.95	15.53	14.74	78.10
30	D. Raudabaugh,	37	May 17,	Nov. 2,	11.54	1.12	0.74	18.63	15.83	15.04	84.98
31	John Rhodes,	35	May 13,	Oct. 13,	9.75	0.81	0.73	17.45	15.25	14.49	86.40
32	John Rhodes,	35	May 15,	Nov. 2,	8.27	0 66	0.58	16.99	14.51	13.78	85.41
33	—— Garman,	36	May 24,	Oct. 14,	6.80	0 65	0.81	18.98	16.09	15.25	85.00
34	—— Garman,	36	May 24,	Nov. 2,	5.66	0.66	0.70	16.97	14.18	13.47	83.56
35	Frank C. Bosler,	18	May 19,	Oct. 11,	8.71	0.42	0.35	16.13	12.03	11.43	74.50
36	Frank C. Bosler,	18	May 19,	Nov. 2,	7.94	0.37	0.82	14.31	11.60	11.02	81.07
37	Wm. Stone,	...	May 21,	Oct. 18,	4.85	0.30	0.31	15.77	13.93	12.28	82.20
38	Wm. Stone,	...	May 21,	Nov. 6,	...	0.30	0.49	15.43	11.56	10.98	74.92
39	Vance McCormick,	26	June 15,	Oct. 23,	15.24	1.34	0.95	16.34	13.08	12.48	79.90
40	Vance McCormick,	26	June 15,	Nov. 9,	10.23	1.00	0.73	18.46	14.65	13.92	79.36
	Average,	...	...	...	9.16	0.68	0.66	17.13	13.91	13.21	81.21
	ELK COUNTY.										
41	*H. R. Manett,*	...	*May 20,*	*Oct. 1,*	...	...	*1.00*	...	*14.2*	*13.5*	*76.3*
42	*H. R. Manett,*	...	*May 24,*	*Oct. 12.*	...	...	*1.06*	...	*13.1*	*12.5*	*78.5*
	Average	...	...	...	...	...	*1.03*	...	*13.6*	*13.0*	*77.4*
	FRANKLIN COUNTY.										
43	W. H. Stamey,	22	May 20,	Oct. 26,	16.66	0.96	0.84	18.57	16.23	15.42	87.60
44	W. H. Stamey,	22	May 20,	Nov. 11,	...	...	1.03	18.87	16.80	15.96	89.03
45	Hon. Jas. W. Carson,	36	June 8,	Oct. 20,	6.10	0.57	0.39	17.04	14.77	14.03	86.50
46	Hon. Jas. W. Carson,	36	June 8,	Nov. 13,	8.82	0 94	0.78	16.58	13.70	13.02	82.63
	Average,	...	...	...	10.53	0.79	0.76	17.81	15.37	14.61	86.30

No.	Name.	Distance apart of rows, inches.	Time of planting.	Time of harvesting.	Yield per acre, tons.	Average weight of one beet, lbs.	Average weight of sample beets, lbs.	Brix density.	Sugar in juice, per cent.	Sugar in beets, per cent.	Purity.
	LACKAWANNA COUNTY.										
47	J. L. Stone,	....	May 15,	Nov. 4,	....	....	1.22	19.33	16.05	15.25	83.04
	LANCASTER COUNTY.										
48	Chas. E. Maule,	32	May 7,	Oct. 7,	6.78	....	2.39	17.93	15.06	14.31	84.00
49	Chas. E. Maule,	32	May 7,	Oct. 7,	6.78	....	2.92	16.52	13.68	13.00	82.81
50	John H. Landis,	30	May 1,	Oct. 9,	....	....	.92	17.09	15.08	14.33	88.24
51	S. N. Mumma,	....	May 14,	Oct. 14,	....	2.49	2.51	17.48	14.12	13.41	80.79
52	John B. Eshleman,	24	May 20,	Oct. 15,	13.06	1.03	1.14	19.98	16.28	15.47	81.84
53	David E. Moyer,	....	May 18,	Oct. 16,	....	1.00	1.17	17.67	14.56	13.83	82.40
54	F. B. Deitrich,	....	May 27,	Oct. 23,	....	....	1.10	18.63	16.02	15.22	86.00
55	John H. Landis,	30	May 1,	Oct. 22,	....	....	1.36	16.10	11.93	11.33	74.10
56	Benj. K. Andrews,	36	May 18,	Oct. 18,	18.51	2.57	3.08	14.95	11.50	10.92	76.93
57	A. H. Brubaker,	36	May 16,	Oct. 26,	26.77	3.25	3.90	18.63	13.88	13.19	74.52
	Average,	....	....	....	14.38	2.06	2.04	17.49	14.21	13.50	81.16
	LAWRENCE COUNTY.										
58	*Wm. A. Clark,*	....	*May 24*	*Oct. 12*	....	....	1.19	....	*16.90*	*16.10*	*79.3*
	LEBANON COUNTY.										
59	*Edward Schuratly,*	....	*June 1*	*Sept. 20*	....	....	*1.50*	....	*15.10*	*14.40*	*79.00*
	MCKEAN COUNTY.										
60	A. B. Armstrong,	....	....	....	....	....	2.98	19.96	16.97	16.12	85.06
	MERCER COUNTY.										
61	J. F. Gilkey,	20	May 31,								
62	T. L. Philips,	28	May 18,	Oct. 6,	18.60	1.50	1.28	19.30	14.93	14.18	77.36
63	T. L. Philips,	28	May 18,	Oct. 26,	18.60	1.50	1.05	19.50	15.06	14.31	77.24
	Average,	....	....	....	18.60	1.50	1.16	19.40	14.99	14.24	77.27

	PERRY COUNTY.										
64	*Silas Wright,*	......	*May 26*	*Oct. 12*	......	......	*2.50*	......	*14.8*	*14.1*	*79.10*
65	*Silas Wright,*	......	*May 26*	*Oct. 12*	......	......	*1.38*	......	*18.1*	*17.3*	*85.3*
	Average,	......	......	......	......	......	*1.94*	......	*16.4*	*15.7*	*82.2*
	WYOMING COUNTY.										
66	**Horace Seamens,**	**18**	**May 12,**	Nov. 1,	**15.24**	1.11	1.12	**22.15**	**16.90**	**16.06**	**76.80**
	YORK COUNTY.										
67	**J. S. Young & Co.,**	**30**	**May 10,**	Nov. 10,	**7.69**	**0.97**	**1.22**	**18.32**	14.50	**13.78**	**79.15**
68	**J. S. Young & Co.,**	**30**	**May 10,**	Nov. 10,	**7.69**	**0.97**	**0.97**	**18.77**	**15.90**	**15.11**	**84.71**
69	*Wm. Hammill,*	......	*May 26*	*Oct. 12*	......	......	*2.69*	......	*15.20*	*14.50*	*80.40*
	Average,	......	......	......	**7.69**	**0.97**	**1.62**	**18.54**	**15.20**	**14.46**	**82.00**

Of the sixty-nine samples reported upon in the above table, fifty-five (or 80 per cent.) showed over 12 per cent. of sugar in the beet. Thirty-four samples (or 49 per cent.) showed a co-efficient of purity of over 80 per cent. Thirty-two out of the total number, or 46 per cent. showed over 12 per cent. of sugar and also over 80 per cent. of purity. In view of the fact that practically all of the beets were raised by farmers who had had no experience in the culture of this plant for sugar, the results must be regarded as decidedly favorable so far as the quality of the beets is concerned.

In forty cases out of the whole number we have data regarding the average weight of the beets. Of these 40 samples, 14 (or 35 per cent.) weighed between .80 and 1.35 pounds; 18 (or 45 per cent.) were below .80 pounds in weight, and 8 (or 20 per cent.) were above 1.35 pounds. It thus appears that, as a rule, the size of the beets was rather small.

Thirty-four of the experimenters reported the yield of beets. In most cases the yield was calculated from that of a comparatively small area, and in many cases there is evidence that the results may be considerably in error. Taking them as they stand, however, 10 (or 29 per cent.) reported a yield of over 15 tons per acre; 2 (or 6 per cent.), a yield between 10 to 12 tons per acre, and 17 (or 50 per cent.), a yield below 10 tons per acre. It thus appears that while, as stated above, the general quality of the beets was good, the yield was rather small.

As stated above, thirty-two of the samples showed more than 12 per cent. of sugar and more than 80 per cent. of purity. Of these 32 experiments, 7 (or 22 per cent.) reported a yield of over 10 tons per acre; 4 (or 13 per cent.), a yield of between 8 to 10 tons per acre; 7 (or 22 per cent.), a yield of less than 8 tons per acre, while 14 (or 44 per cent.) did not report the yield. These figures confirm those given above in showing that the yield was, as a whole, rather small.

The experiments are too few in number to permit any reliable conclusions to be drawn as to the influence of locality. So far as the results show, good beets and poor beets have been raised in all portions of the State.

The following are the results obtained upon the two other varities purchased by Mr. Bosler:

Name.	Postoffice.	Variety.	Soil and Culture.
Frank C. Bosler,	Carlisle,	White Silesian,	Rich garden soil, used as a garden for 10 years; beets hoed four times.
Frank C. Bosler,	Carlisle,	White Silesian,	The same.
John Rhodes,	Carlisle,	White Silesian,	Clay loam; beets cultivated three times.
John Rhodes,	Carlisle,	White Silesian,	The same.
John Beltzhoover,	Carlisle,	White Silesian,	Gravelly loam; beets harrowed three times.
John Beltzhoover,	Carlisle,	White Silesian,	The same.
Vance McCormick,	Carlisle,	White Silesian,	Loose gravel soil.
Vance McCormick,	Carlisle,	White Silesian,	The same.
Frank C. Bosler,	Carlisle,	Lane's Imperial,	Rich garden soil, used as a garden for 10 years; beets hoed four times.
Frank C. Bosler,	Carlisle,	Lane's Imperial,	The same.
Wm. Weary,	Carlisle,	Lane's Imperial,	Limestone clay; old garden.
Wm. Weary,	Carlisle,	Lane's Imperial,	The same.
Vance McCormick,	Carlisle,	Lane's Imperial,	Loose gravel soil.
Vance McCormick,	Carlisle,	Lane's Imperial,	The same.

Name.	Distance apart of rows, inches.	Time of planting.	Time of harvesting.	Yield per acre, tons.	Average weight of one beet, lbs.	Average weight of sample beets, lbs.	Brix density.	Sugar in juice, per cent.	Sugar in beets, per cent.	Purity.
Frank C. Bosler,	18	May 23,	Oct. 11,	16.11	0.71	0.92	11.78	7.02	6.67	59.60
Frank C. Bosler,	18	May 23,	Nov. 2,	15.24	0.65	0.73	14.31	13.36	12.69	93.23
John Rhodes,	37	May 18,	Oct. 13,	23.13	1.82	1.54	13.36	10.03	9.53	75.20
John Rhodes,	37	May 18,	Nov. 2,	8.27	0.66	0.82	14.31	11.35	10.78	79.32
John Beltzhoover,	39	May 19,	Oct. 14,	4.99	0.42	0.55	14.79	12.44	11.82	84.60
John Beltzhoover,	39	May 19,	Nov. 2,	7.51	0.73	0.73	12.96	10.76	10.22	83.03
Vance McCormick,	26	May 15,	Oct. 23,	13.93	0.76	0.74	13.47	9.76	9.28	72.60
Vance McCormick,	26	May 15,	Nov. 9,	16.83	1.41	0.92	15.26	12.38	11.76	81.14
Frank C. Bosler,	18	May 23,	Oct. 11,	18.94	0.77	1.03	13.98	9.56	9.08	68.40
Frank C. Bosler,	18	May 23,	Nov. 2,	18.73	0 74	0.71	14.56	13.70	13.10	94.10
Wm. Weary,	13	June 1,	Oct. 14,	22.90	0 82	0.96	11.35	6.85	6.51	61.00
Wm. Weary,	13	June 1,	Nov. 4,	21.99	0.82	0.89	12.83	7.93	7.53	61.82
Vance McCormick,	26	June 15,	Oct. 23,	18.56	1.34	0.83	11.14	7.59	7.21	62.90
Vance McCormick,	26	June 15,	Nov. 9,	17.42	1.40	1.05	14.94	10.95	10.40	73.30

It appears from the above results that while, in a few cases, these varieties yielded good beets, as a whole they were inferior to those reported in the larger table above.

THE SEASON.

As is well known, the season exerts a most important influence upon any crop, and this is particularly true of the sugar beet. Comparing the growing season of 1898 with the average for several years past in the counties in which the experiments were made, we have the following results, taken from the records of the State Weather Service.

	Temperature, Degrees F.		Rainfall.		
	Mean.	Departure from normal.	Total inches.	Departure from normal, inches.	Number of rainy days.
Allegheny County—Pittsburg.					
May,	58.0	—4.0	2.70	—0.71	15
June,	68.0	—4.0	2.97	—0.53	11
July,	76.0	+2.0	4.52	—0.40	15
August,	70.5	—2.5	2.08	—1.10	12
September,	68.0	+2.0	1.65	—0.98	7
October,	59.0	+4.0	0.12	—2.21	2
Bradford County—Le Roy.					
May,	55.0	—1.8	4.84	—0.46	14
June,	61.6	—6.2	3.77	—0.70	14
July,	71.9	+2.7	3.95	+0.40	12
August,	65.2	—2.7	4.40	+0.53	11
September,	60.8	—1.2	3.08	—0.33	8
October,	52.0	+4.2	1.30	—2.28	6
Bucks County—Forks of Neshaminy.					
May,	64.3	+4.4	6.34	+0.41	12
June,	67.4	—3.2	6.42	+2.49	12
July,	75.0	+2.0	12.42	+7.48	17
August,	72.0	—0.1	3.09	—0.41	17
September,	65.3	+0.1	1.31	—2.87	4
October,	54.8	+2.7	2.41	—1.41	7
Centre County—State College.					
May,	57.6	—0.8	4.12	—1.35	12
June,	64.1	—4.2	3.03	—0.67	12
July,	71.5	+2.1	5.69	+2.17	18
August,	66.0	—2.5	3.39	—0.99	10
September,	63.7	+1.5	3.60	+0.69	7
October,	53.6	+4.9	1.45	—1.60	4
Chester County—Kennett Square.					
May,	60.7	+1.0	7.96	+2.46	14
June,	66.3	—4.1	2.78	—0.36	12
July,	74.8	+2.5	10.16	+5.17	16
August,	71.7	+0.6	2.77	—2.02	11
September,	66.9	+1.7	1.63	—3.61	4
October,	56.6	+5.0	2.19	—1.39	7
Clearfield County—Grampian.					
May,	55.4	—1.4	4.55	+0.12	11
June,	63.7	—3.3	3.14	—1.12	10
July,	72.7	+2.3	7.02	+2.19	19
August,	66.5	—1.3	2.46	—1.65	9
September,	62.1	+1.3	3.16	—0.20	8
October,	52.6	+4.9	0.68	—2.20	5
Crawford County—Saegerstown.					
May,	53.7	—2.2	3.95	—2.64	12
June,	61.2	—6.4	3.58	+0.26	10
July,	71.1	+3.2	14.51	+11.95	15
August,	64.0	—2.8	6.03	+2.39	12
September,	60.4	—1.2	1.55	—2.38	3
October,	53.6	+5.3	0.50	—1.96	5

	Temperature, Degrees F.		Rainfall.		
	Mean.	Departure from normal.	Total inches.	Departure from normal, inches.	Number of rainy days.
Cumberland County—**Carlisle.**					
May,	60.3	—0.3	6.54	+2.79	11
June,	67.4	—3.8	1.52	—2.22	9
July,	76.0	+1.2	4.42	+0.93	....
August,	70.4	—2.3	5.12	+0.41	10
September,	66.8	....	2.97	—0.91	4
October,	54.6	+2.5	2.06	—1.48	6
Elk County—**St. Marys.**					
May,	58.7	....	3.44	....	13
June,	60.9	....	2.13	....	10
July,	70.2	....	5.91	....	13
August,	63.8	....	2.54	....	9
September,	61.0	....	2.85	....	4
October,	51.4	....	0.97	....	4
Franklin County—**Chambersburg.**					
May,	57.6	—2.3	5.03	—0.50	13
June,	66.1	—3.4	1.22	—2.92	11
July,	74.0	—0.9	4.22	+2.40	12
August,	68.3	—3.7	6.02	+1.48	9
September,	60.8	....	3.08	+0.24	6
October,	52.3	+2.4	2.19	—1.64	7
Lackawanna County—**Scranton.**					
May,	58.0	....	4.82	....	10
June,	63.2	....	3.43	....	10
July,	72.4	....	5.00	....	13
August,	68.0	....	2.57	....	5
September,	62.5	....	1.20	....	6
October,	53.5	....	1.10	....	5
Lebanon County—**Lebanon.**					
May,	59.8	+0.2	6.52	+0.42	12
June,	66.4	—3.7	3.00	+0.02	15
July,	75.0	+3.8	5.89	+1.25	12
August,	70.0	—1.1	2.51	—2.02	10
September,	65.7	+1.5	1.57	—2.03	5
October,	54.6	+3.8	2.36	—1.27	6
McKean County—**Smethport.**					
May,	53.2	—2.0	2.90	—3.99	10
June,	60.4	—5.9	2.95	—1.61	11
July,	....	....	....	....	....
August,	63.0	—2.5	3.25	—1.25	7
September,	....	....	....	....	....
October,	50.4	+3.3	0.65	—3.23	4
Mercer County—**Greenville.**					
May,	54.3	—2.4	4.10	+1.24	13
June,	63.2	—3.8	3.55	—0.14	12
July,	70.8	+1.8	8.16	+5.45	9
August,	64.0	—1.9	4.88	+2.42	11
September,	58.8	—1.1	1.91	—3.06	3
October,	51.1	+4.3	0.47	—2.88	5
Perry County—**Aqueduct.**					
May,	62.4	—0.5	5.93	—0.37	12
June,	68.7	—4.1	2.93	—0.37	13
July,	78.0	+3.9	3.78	—0.10	12
August,	71.2	—0.9	2.72	—1.40	9
September,	66.2	+0.3	2.66	—0.84	5
October,	55.6	+3.4	2.34	—1.18	7
Wyoming County—**South Eaton.**					
May,	56.8	—0.4	5.29	+0.32	10
June,	62.2	—5.9	3.92	+0.91	14
July,	72.0	+3.3	3.38	+0.15	10
August,	66.8	—1.4	3.23	—0.81	9
September,	61.6	+0.6	2.24	—0.23	6
October,	52.6	+3.7	1.12	—2.37	5
York County—**York.**					
May,	60.1	—0.8	6.61	+1.92	13
June,	66.8	—3.9	2.42	—0.97	14
July,	75.7	+2.9	3.69	—0.50	10
August,	70.0	—2.2	4.04	+0.42	10
September,	65.0	—0.8	2.73	—1.61	5
October,	55.0	+3.7	2.60	—0.63	7

The above records may be summarized in the following table, which shows the number of localities in which the temperature or the rainfall, or both, were either above or below the average for previous years:

	Temperature and rainfall both above normal.	Temperature above normal, rainfall below.	Temperature below normal, rainfall above.	Both below normal.
May,	2	0	5	7
June,	0	0	3	11
July,	9	4	0	0
August,	0	1	6	7
September,	1	6	0	4
October,	0	14	0	0

It appears from this summary that May was generally cool, with a rainfall in some cases in excess and in some cases below the average. June was generally cool, with a deficiency of rainfall. July was hot, with an excess of rainfall. August, September and October, particularly the latter month, were hot and increasingly dry.

This hot and dry weather during the latter portion of the growing season is probably reflected in the generally small size and yield of the beets, and it may be anticipated that with a more normal season a larger tonnage would be obtained. The small yields may be due in part also to the instructions given. In these, farmers were warned against excessive use of manure as tending to increase the size of the beets at the expense of their quality. On the other hand, it is generally found that small beets are richer in sugar than large ones, and the small size of the beets may have had a tendency to make the results as to quality better than would be obtained in an average year. Some of the samples, too, were somewhat wilted when they were analyzed and this would have a tendency in the same direction. On the other side of the question, however, there is to be considered, as already pointed out, the lack of experience on the part of the growers. A number of very excellent results were obtained and taking into account all the uncertainties as to the actual yields obtained and possible mistakes in sampling as well, the outlook on the whole appears encouraging.

FUTURE PROSPECTS.

The first question which presents itself to the farmer is whether it will pay him to raise sugar beets for sale to a factory. The experiments here reported were made on the small scale and afford no reliable data as to the cost of raising a crop. The figures and estimates as to the cost of raising beets which are given by large growers in other states are quite variable, ranging all the way from $20 to $70 per acre. A conservative estimate, however, is from $30 to $40 per acre, although the cost will naturally depend upon local conditions and especially upon the experience and intelligence of the grower. The general experience in other states has been that the second years' crop has been produced much more cheaply than the first year's.

The price paid for beets at the factory depends chiefly upon the market price of sugar and upon the richness of the beets, but also upon local conditions. Assuming four dollars as an approximate average price for this country, the profits of the grower will depend largely upon the tonnage of good beets which he is able to produce. Ten tons per acre seems to be generally regarded as a fair crop, although good land and careful cultivation should produce twelve to fifteen tons. According to these figures, the total value of the crop at the factory would range from $40 to $60 per acre.

Feeding Value of Residues. To the above estimates is to be added the feeding value of the diffusion residues, or pulps, from the manufacture of sugar. These constitute a palatable and nutritious food for stock and in all beet-sugar growing countries the keeping of live stock is regarded as an important adjunct to the growing of beets. It is impossible to fix any money value upon these residues, but we are probably safe in assuming them as roughly equivalent in feeding value to half their weight of mangels. It is also estimated by good authorities at from one-fourth to one-fifth of the value of the beets. The molasses, too, which is a by-product of the sugar manufacture has a not inconsiderable feeding value, and the same is true of the leaves and crowns of the beets. Moreover, when these by-products are returned to land there is little or no draft upon its fertility, since pure sugar contains neither nitrogen, phosphoric acid nor potash.

WHAT TO DO NEXT.

A beet sugar factory must necessarily have a large territory tributary to it. The best authorities estimate the minimum capacity of a profitable sugar beet factory at 300 tons per day. In other words, such a factory would eat up daily the product of 30 acres, producing 10 tons of beets per acre. For a season of 70 days this is equivalent to the product of 2,100 acres. This means that to make a beet sugar factory a success, there must be a large number of skilled beet growers, and that these must be so located that the transportation of the beets to the factory will not cost too much.

Evidently, then, if the farmers of any locality desire to secure the erection of a beet sugar factory they must do two things:

1. They must learn to grow good sugar beets. There is no difficulty in growing a large crop of beets, but unless they are of the requisite quality, successful sugar manufacture cannot be carried on. A crop of beets containing seven or eight per cent. of sugar, however large, is of no more value to a sugar factory than so many potatoes.

2. They must see whether their soil and climate and conditions are adapted to the profitable culture of the sugar beet.

Where the interest in the matter is general, a sugar beet association should be formed and an earnest endeavor should be made to secure the active co-operation of as many farmers as possible. They should be induced to inform themselves thoroughly during the present winter regarding the culture of the sugar beet and arrangements should be made to have as many of them as possible grow an acre or two of beets during the coming season and keep a careful record of the cost and the yield secured. Since true sugar beet seed is expensive, it would probably not be necessary to use enough of it to plant an acre but a small patch of the true beets might be surrounded with a larger area planted with cheaper seed. If possible, some energetic and efficient man should be appointed to supervise these experiments and records, seeing that the yields are accurately determined and samples properly taken for analysis and promptly forwarded to the Experiment Station.

CO-OPERATION BY THE EXPERIMENT STATION.

The Experiment Station expects to have a supply of genuine sugar beet seed for distribution to such responsible farmers or associations as will undertake to conduct experiments like the above and report the results and send samples to it. It will undertake to analyze all samples of beets taken in accordance with its instructions and accompanied by sufficiently full records of culture and yield to make the results of general interest. It is desired that all wishing to undertake such experiments should correspond with the Station as early as practicable in order that arrangements may be made for a sufficient supply of seed and also for pushing forward the analyses in the fall.

SOURCES OF INFORMATION.

The literature of beet sugar in the English language is not extensive. For general use the most available publication is Farmers' Bulletin No. 52 of the United States Department of Agriculture, prepared by Dr. H. W. Wiley, entitled "The Sugar Beet." This bulletin can be had gratis upon application to the Secretary of Agriculture. A large amount of more detailed information and experimental results is on record in the publications of the Department, particularly in Bulletins 27, 30, 33, 36 and 39 of the Division of Chemistry, but unfortunately these are now out of print. The "Sugar Beet," published by Lewis S. Ware, of Philadelphia, is the oldest and only journal in this country devoted exclusively to the interests of the sugar beet. This gentleman has also published a book upon this subject, also entitled "The Sugar Beet," treating quite elaborately of the subject. One of the latest publications is "Sugar," by Herbert Myrick, editor of the "American Agriculturist," published by the Orange Judd Co.

PLOT EXPERIMENTS WITH LEGUMES.*

BY W. S. SWEETSER.

PRELIMINARY REMARKS.

It seems to be the tendency throughout nature for the element nitrogen to revert from the forms which are available as plant and animal food back into the atmosphere. Bacteria and ferments are busily engaged all about us to bring about this change. The proteid matter of both animal and vegetable bodies is undergoing decay, and even if it is not changed so as to liberate nitrogen into the atmosphere, it is changed to those compounds which are readily soluble in water and are carried by that solvent down into the sub-strata of the soil or into the streams, thence into the sea, in both cases out of reach of terrestrial plant and animal life. Again, we have the sewers of our cities and large towns continually carrying an immense amount of nitrogenous plant food into rivers and the sea, never to be recovered to the land inhabitants.

The earth in its soil and mineral deposits holds in reserve an inexhaustible store of the other elements of plant food which are valued as fertilizers, viz., phosphoric acid and potash. But this is not at all the case with respect to nitrogen, the most expensive of all. We have deposits of nitrates, but these would be but meagre if they were not supplmented by a supply of nitrogen in ammonia salts and organic compounds, such as dried blood, tankage, fish scrap, guano, castor pomace, cotton-seed meal and bone.

All compounds used as a source of nitrogen for plant food are either organic or have been formed from organic matter. And all of this organic matter must have originally come from an inorganic source. The question naturally arises, how has this store of organic nitrogen and those compounds formed from it been formed from inorganic matter? Ammonia salts and nitrates are being slowly formed in the atmosphere by electric discharges, evaporation of water, etc., and thence brought to the earth by the rains. In these forms, the nitrogen is available as plant food. Much organic nitrogen from the decay of which the nitrate beds have probably been formed, may have accumulated in this way in prehistoric times. But at the present state of things this source would be far from adequate to serve all the agricultural crops with their requisite amount of nitrogen.

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*Thesis for degree of M. S. in Agriculture.

Until within fifteen years, it was a disputed question whether plants have any power of assimilating the free nitrogen of the air. At about that time the results of conclusive experiments began to be published, showing that plants belonging to the great family leguminoseae, which comprises the clovers, lupines, vetches, peas, beans, alfalfa, etc., have the faculty under favorable conditions, of assimilating large quantities of free atmospheric nitrogen. This faculty Hellriegel proved to be due to the action of bacteria which tenant the nodules so common on the roots of healthy leguminous plants. This is believed to be a case of symbiotic action in which the bacterial cell feeds upon the root cell and takes nitrogen from the air. By some process it is thought to turn this nitrogen over to the plant or root cells in some assimilable form.

Atwater's* experiments on peas and alfalfa indicate that in the absence of nodules on the roots there was no gain in nitrogen over the amount furnished the plants, but rather a loss. In the presence of a large number of nodules there was a decided gain. He divided his plants into three or more classes, viz., those having none or a few root nodules, those having a fair number, and those having a large number. With those of the first class, there was invariably a loss of nitrogen or a very slight gain. With the peas of the second class, comprising twelve experiments, 25.3 per cent. of the nitrogen content of the plants was acquired from the atmosphere and in the last class, comprising twenty nine experiments, there was an average of 36.7 per cent. of the nitrogen taken from the atmosphere.

These discoveries in regard to legumes and their power to assimilate free atmospheric nitrogen through the symbiotic action of the bacteria resident in their root nodules has furnished something of a clue to the question advanced. Whence a requisite supply of nitrogen to meet the enormous waste that is going on about us? How can the farmer supply his crops and animals with that expensive element of their food when the supply from accumulated deposits would grow less and less? He can do it by availing himself of the fruits of the above discovery, which is one of the most important, if not the most important, contributed by agricultural science to the economy of the human race.

Following is a brief description of the legumes which were selected for experiment:

FLAT PEA (LATHYRUS SILVESTRIS).

This will make a good yield of fodder upon almost any soil, but an especially heavy growth upon lime soil. No working of the soil and no nitrates are necessary. The young plants may be planted in late summer, and during the first year there is a rank growth of rhizomes, or underground stems. It is claimed that one crop may be cut the next season after planting, and two crops every year thereafter for fifty years or more. For fodder, the vines should be cut just before the flowers mature. The claim has been made that the flat pea gives a greater yield than any other crop. Some report that the stock eat it eagerly, while others state the contrary to be the case. Our experience has been that the cattle would not touch it, although the vines were cut when they were very tender and succulent, in fact, even before the plants were in bloom. But it is a well known fact that there are plants which some cattle will not eat at first, but will eat the same greedily after bcoming accustomed to them. Undoubtedly, the flat pea is one of this class.

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*Report of Storr's School Experiment Station, 1889.

CANADA FIELD PEA.

This crop is a very important one in Canada, but has not been raised to any great extent in this country. It grows quickly, stands fairly well if the season is not too wet, and gives a good crop of excellent fodder, which is relished by stock, even if the vines are not cut until the peas are ripe. The crop should be harvested previous to this stage, however, to avoid loss by shelling. The ground is left in excellent condition for rye or winter wheat. The popularity of this crop would, no doubt, be greatly increased by improved harvesting machinery, which is used to some extent in Canada at the present time. It has been recommended to sow these peas with oats or barley, three bushels of peas to one of grain, or to two-thirds of a bushel of the grain if it is likely to stool very well. Pea meal needs no recommendation as to its qualities for stock-feeding on account of the high percentage of protein which it contains.

VETCHES.

The vetches have been very poular in England and have reason to become favorites in this country for certain uses. They are most at home in a limestone soil and have been recommended as especially well adapted as a cover crop for orchards. They should be cut when in bloom or just before, although the time depends somewhat upon the kind of stock to which they are to be fed.

The spring vetch (Vicia sativa) is a slender twining plant, which is sown early in the spring and grows rapidly. Its great disadvantage is it becomes matted on the ground and there decays if the season is wet. It is well to sow with oats or barley which support the vines to some extent. One bushel of oats or barley to two bushels of vetch is about the right proportion.

Sand, fall or hairy vetch (Vicia villosa), is sown early in the fall, makes a fair growth that season and in the spring makes a rapid growth. In this section, it is usually ready to cut by the middle of June. Rolling in the spring results in a more rapid and uniform growth.

MEDIUM RED CLOVER (TRIFOLIUM PRATENSE).

This plant is too well known to need much description here. It was one of the first forage plants to be brought under cultivation, and is at present the most common of all leguminous forage crops with us. The plant varies in different localities, but in most cases it is a perennial of but a few years' duration. It thrives best, perhaps, on fertile, well-drained clay soil, rich in lime and potash. It should be sown in the early spring, and later on the ground should be rolled. The crop is in the best stage for cutting when about two-thirds of the heads are past bloom. Much nourishment is drawn from the sub-soil by the long, penetrating tap roots and when these decay, the land is left in an excellent mechanical condition. In fact, as a preparation for wheat, clover may be said to be without a rival. In curing, an important point is that the crop should be gathered into small bunches soon after it is wilted and the leaves and stems allowed to sweat and cure together. Otherwise, the leaves, which are the most valuable part of the plant will become brittle and, consequently, break off in handling, while the thick leathery stem is scarcely cured.

WHITE OR DUTCH CLOVER (TRIFOLIUM REPENS).

This is also a well-known plant, but is not valued except for pastures and lawns. It is not sown to any great extent, but works its way into pastures and furnishes an excellent feed. It stands drought well and seeds freely, the seeds living in the soil several years. Undoubtedly, this small plant is of much value in bringing a supply of nitrogen to the soil from the atmosphere for the use of the pasture grasses. It is not sown as a field crop, probably on account of its size and the small crop which it is thought to produce. On this latter point, very likely the prevailing opinion is at fault. Under unfavorable conditions, it has produced ten tons of green fodder to the acre when the medium red and alsike clover, under conditions as nearly the same as possible, produced only eight and nine tons, respectively.

ALSIKE OR SWEDISH COLVER (TRIFOLIUM HYBRIDUM).

This is smaller than the medium red clover and has a pinkish white blossom, somewhat larger than that of white clover. It does not produce as much hay as the former, but it is of excellent quality. It is more strictly a perennial than is the medium red and is better adapted to cold, wet soils. When the conditions are suitable, it grows with great luxuriance and is especially worthy of a trial in these limited areas.

CRIMSON CLOVER (TRIFOLIUM INCARNATUM).

This is an annual, introduced from Southern Europe, where it is raised extensively. It grows about two feet high and has long, bright crimson heads. It has recently come into prominence in this country as a soiling crop. In this locality, for the surest results, it should be sown soon after the middle of July. Some have recommended sowing it between the rows of corn when cultivated the last time. Crimson clover is said to be of excellent service in orchards in preventing the ripe fruit from becoming soiled. The following spring it may either be harvested or plowed under as a green manure. The crop is usually harvested in May and should be cut as soon as it is in full bloom. If allowed to stand longer, serious trouble may result from hair balls being found in the stomachs of the stock, horses especially.

ALFALFA, OR LUCERNE (MEDICAGO SATIVA).

This plant does not seem to be generally adapted to the soil and climate of the northern and middle states. It flourishes in a warm, dry climate over a sub-soil that is porous enough to permit the roots to grow unchecked to a depth of from ten to twelve feet. The hard, clay sub-soil of the north and east is decidedly against its growth. It is adapted to irrigation and is much grown in that way in the far west and southwest. It yields immense crops, often as large as five or six tons of dry fodder per acre. It has been grown successfully in Geneva, N. Y., for several years and numerous experiments have shown it to do well in several other restricted localities in the northern states.

The following table shows the average composition of the above fodders, calculated to a water-free basis. The composition of timothy is inserted for comparison:

Percentage Composition.

	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.
Flat pea,	8.6	25.0	28.6	34.3	3.5
Canada field pea,	10.2	14.1	31.0	41.5	3.1
Vetch,	8.9	19.2	28.6	40.7	2.6
Medium red clover,	7.3	14.5	29.1	45.2	3.9
White clover,	9.2	17.4	26.7	43.5	3.2
Alsike clover,	9.3	14.2	28.4	44.9	3.2
Crimson clover,	9.5	16.8	30.1	40.5	3.1
Timothy,	5.1	6.8	33.5	51.7	2.9

PLOT EXPERIMENT.

The purpose of the experiment was to make a comparative test of the efficiency of different leguminous crops and their adaptability to the soil and climate of this section. Eight plots of one-twentieth acre each were selected, which had had similar fertilization in previous years, but none since the spring of 1893. These plots were seeded as follows, without any application of fertilizer:

Plot 1, Medium red clover,	14 lbs. per acre.
Plot 2, White clover,	10 lbs. per acre.
Plot 3, Alsike clover,	10 lbs. per acre.
Plot 4, Timothy,	24 lbs. per acre.
Plot 5, Crimson clover,	20 lbs. per acre.
Plot 6, Canada field pea,	90 lbs. per acre.

Plot 7, Alfalfa, ...	25 lbs. per acre.
Plot 8, Spring vetch, ...	60 lbs. per acre.

These plots were seeded April 30, 1896, by hand, and the seed was covered by a Breed weeder. The timothy was entered merely as a matter of comparison to show the contrast in certain respects between it and the legumes. The soil was a clay loam, with good underdrainage. Four other plots were reserved for later seeding, as follows: Nos. 9 and 10 and 11 with crimson clover, 20 lbs. per acre, on July 15, August 15 and September 1, respectively. Plot 12 was sown with sand vetch, 60 lbs. per acre, on September 1. A plot of flat pea, two years old, and adjacent to the above plots, was entered into the experiment. All the plots were kept free as possible from weeds and the following points were noted concerning the condition of the crops:

Plot 1, Medium Red Clover. The plot was very weedy during the first part of the season, and the plants seemed to have a poor chance. Once, in May, the weeds were mown just above the tops of the clover plants. In the latter half of the summer the clover took a start, and, by September, looked very promising. The following spring it made a good growth and was cut June 29, when about one-half of the heads were past bloom.

Plot 2, White Clover. The seed germinated well, and the plants looked well all through the season. The weeds were cut with a scythe just above the clover plants on June 26. This plot continued to look well all through the experiment. It was cut on June 23, 1897, when it was somewhat past bloom and matted so that it was impossible to cut it clean with a scythe.

Plot 3, AlsikeClover. The plants came up well and promised well all through the season. The weeds were cut, as above, the last week in June. The crop was cut on June 23, 1897, when it was in good condition in every way.

Plot 4, Timothy. The seed germinated well and the grass did fairly well all through the season. The weeds were cut once, in the last week in June. The next spring, the grass started well, but was thin and small, showing a lack of nourishment. The crop was cut on July 13, 1897.

Plot 5, Crimson Clover. The seed germinated well and grew fairly well during the first part of the season, but did not attain any great height. It blossomed very unevenly, so that when it was cut, on August 17, some was still in bloom and some far past that stage.

Plot 6, Canada Field Pea. This plot did well from the start. It was weeded by hand on June 26, in full bloom by July 7, and cut on July 30, when some of the pods were yellow and nearly ready to open. The cattle ate the fresh fodder up clean, except the lower portions of the stems, which had been rotted by the wet weather.

Plot 7, Alfalfa. The plants came up well and looked thrifty for the first two months. Then they began to turn yellow and look sickly all through the season. The plot was abandoned the following spring.

Plot 8, Spring Vetch. This came up well and did fairly well until it bloomed in July. Soon after this, it became infested with blister beetles, which ate the upper leaves and blossoms, preventing the formation of pods. When cut, on September 23, the plants were in poor condition. There were few pods, and the lower part of the stalks were brown and lifeless.

Plot 9, Crimson Clover (sown July 16). It came up and did fairly well all through the season. It started well the next spring, made a good growth and was cut in full bloom on May 27.

Plot 10, Crimson Clover (sown September 1). This came up well, and seemed to do well through the season, but did not attain the size of that on Plot 9 when winter set in. None was winter-killed as far as observed, but the plants could not seem to make the rank growth of that on the above plot. It was cut in full bloom on May 27.

Plot 11, Crimson Clover (sown September 1). This also came up well, but it had not time to make much growth before winter, and it amounted to nothing the next spring.

Plot 12, Sand, or Winter Vetch. This plot was seeded on September 15, and the seed came up well. The ground was covered before winter. The following spring, the plants grew well and were in full bloom on June 13. Soon they began to die below, but were still growing at the top. The crop was cut on June 28. The roots were found to be in a very weak condition and had few nodules.

.Plot 13, Flat Pea. This plot had a very rank growth and was cut on July 8, before it was blooming. The cows would not touch the green tops.

Just previous to cutting each of the above crops, a plot of sixteen square feet was set off which was as nearly as possible a fair average of the whole plot. The tops of this section were cut and immediately weighed. Then the roots, to a depth of two feet, were separated from the soil by sifting. These were washed free from soil, well drained and weighed. The total dry matter, ash, nitrogen, phosphoric acid, potash and lime were determined in each sample of tops and roots.

The nitrogen was determined by the Kjeldahl method, the potash by digesting in strong sulphuric acid, igniting, and proceeding as by the Lindo-Gladding method. In determining the phosphoric acid, the ash was dissolved in nitric acid, plus a few drops of hydrochloric acid. After filtering, a few crystals of ammonium nitrate were added and the phosphoric acid precipitated by ammonium molybdate solution. After digesting for one-half hour at a temperature not exceeding 60 degrees C., it was filtered, cold, dried and weighed as ammonum phosphomolybdate, factor for phosphoric acid, .0367. The lime was determined by dissolving five grains, after incinerating, in hydrochloric acid and making up to 250 cc. Fifty cc. of this were run into a beaker, alkalized with ammonia and then acidified with acetic acid. The lime was then precipitated by ammonium oxalate and washed thoroughly with hot water. After dissolving the calcium oxalate in warm dilute sulphuric acid, the oxalic acid thus set free was titrated against a potassium permanganate solution of such a strength that 10 cc. equals 1 per cent., CaO. This solution has been titrated against an oxalic acid solution, 2.25 grams to the liter. The above method had given excellent results with a test solution containing iron, aluminum, magnesium, phosphoric acid and a known amount of lime.

Table I shows the loss by drying at a temperature of 60 to 70 degrees, C., and then exposing to the laboratory atmosphere for at least twenty-four hours. This table also shows the results of a partial analysis after such treatment. Table II gives the contents of Table I, computed to a fresh basis. Table III gives the number of pounds per acre of the several ingredients and Table IV the same ingredients of the entire plant.

I. PERCENTAGE COMPOSITION

	Number of plot.	Loss in air-drying.	Air-dried Substance.						
			Moisture.	Ash.	Organic matter.	Nitrogen.	Phosphoric acid.	Potash.	Lime.
Flat pea, tops,	13	75.54	8.92	7.93	83.15	2.79	.57	1.87	1.46
Flat pea, roots,	13	77.37	5.83	11.38	82.79	1.81	.39	1.24	.86
Canada field pea, tops,	6	78.80	7.80	13.31	78.89	2.53	.67	1.21	1.63
Canada field pea, roots	6	78.76	8.31	15.49	76.20	2.14	.62	.73	1.12
Spring vetch, tops,	8	27.73	7.04	8.92	84.04	1.88	.79	2.08	2.16
Spring vetch, roots,	8	77.99	6.30	9.32	84.38	1.77	.64	1.27	1.37
Sand vetch, tops,	12	60.00	7.79	8.12	84.09	2.75	.79	1.86	1.45
Sand vetch, roots,	12	84.61	7.61	13.39	79.00	1.81	.55	1.05	1.46
Medium red clover, tops,	1	70.40	8.54	6.63	84.83	1.74	.45	2.24	1.37
Medium red clover, roots,	1	77.10	7.41	10.15	82.44	1.90	.59	1.41	.95
White clover tops,	2	77.36	9.85	8.85	81.30	2.76	.80	3.10	1.61
White clover, roots,	2	78.45	8.08	13.17	78.75	1.96	.60	1.54	.90
Alsike clover, tops,	3	72.20	9.27	7.95	82.78	1.96	.66	2.87	1.49
Alsike clover, roots,	3	77.02	6.50	12.22	81.28	1.64	.36	1.47	1.01
Crimson clover, tops,	5	71.00	6.08	10.01	83.91	2.28	.57	2.03	1.84
Crimson clover, roots,	5	80.79	6.21	19.33	74.46	1.47	.42	1.07	1.10
Crimson clover, tops,	9	84.24	8.47	7.78	83.75	2.48	.54	2.30	1.79
Crimson clover, roots,	9	80.60	7.99	12.03	79.98	1.77	.81	1.84	1.23
Crimson clover, tops,	10	86.55	9.04	8.08	82.88	2.32	.55	1.95	2.02
Crimson clover, roots,	10	55.56	8.55	11.30	80.15	1.55	.31	1.23	1.68
Timothy, tops,	4	54.98	6.20	5.05	88.75	.73	.45	1.54	.48
Timothy, roots,	4	77.10	7.24	11.82	80.94	.66	.36	.73	.58

II. PERCENTAGE COMPOSITION OF FRESH SUBSTANCE.

	Number of plot.	Total moisture.	Ash.	Organic matter.	Nitrogen.	Phosphoric acid.	Potash.	Lime.
Flat pea, tops,	13	77.72	1.94	20.34	.682	.140	.457	.357
Flat pea, roots,	13	78.69	2.58	18.73	.410	.088	.281	.195
Canada field pea, tops,	6	80.45	2.82	16.73	.536	.141	.257	.346
Canada field pea, roots,	6	80.53	3.29	16.18	.455	.132	.155	.238
Spring vetch, tops,	8	32.82	6.45	60.73	1.358	.572	1.508	1.561
Spring vetch, tops,	8	79.38	2.05	18.57	.388	.140	.280	.302
Sand vetch, tops,	12	63.12	3.25	33.63	1.100	.317	.744	.580
Sand vetch, roots,	12	85.78	2.06	12.16	.279	.084	.162	.225
Medium red clover, tops,	1	72.93	1.96	25.11	.515	.132	.663	.406
Medium red clover, roots,	1	78.80	2.32	18.88	.435	.135	.323	.218
White clover, tops,	2	79.59	2.00	18.41	.625	.180	.702	.365
White clover, roots,	2	80.19	2.84	16.97	.422	.130	.332	.194
Alsike clover, tops,	3	74.78	2.21	23.01	.545	.182	.798	.414
Alsike clover, roots,	3	78.51	2.81	18.68	.377	.082	.338	.232
Crimson clover, tops,	5	72.76	2.90	24.34	.661	.166	.589	.534
Crimson clover, roots,	5	81.98	3.71	14.31	.282	.080	.206	.211
Crimson clover, tops,	9	85.57	1.23	13.20	.391	.085	.363	.282
Crimson clover, roots,	9	82.15	2.33	15.52	.343	.061	.357	.289
Crimson clover, tops,	10	87.77	1.09	11.14	.312	.074	.262	.272
Crimson clover, roots,	10	59.36	5.02	35.62	.689	.139	.591	.747
Timothy, tops,	4	57.76	2.27	39.97	.329	.204	.693	.216
Timothy, roots,	4	78.76	2.71	18.53	.151	.082	.167	.183

III. POUNDS PER ACRE.

	Number of plot.	Total yield.	Dry matter.	Ash.	Organic matter.	Nitrogen.	Phosphoric acid.	Potash.	Lime.
Flat pea, tops,	13	25,560	5,696	497	5,199	174.3	35.8	116.8	91.3
Flat pea, roots,	13	15,852	3,377	409	2,968	65.0	14.0	44.5	30.9
Canada field pea, tops,	6	20,142	3,937	568	3,369	108.0	28.4	51.8	69.7
Canada field pea, roots	6	1,440	281	47	234	6.6	1.9	2.2	3.4
Spring vetch, tops,	8	8,832	5,934	570	5,364	119.9	50.5	132.7	137.9
Spring vetch, roots,	8	1,968	393	39	354	7.4	2.7	5.3	5.8
Sand vetch, tops,	12	6,756	2,492	220	2,272	74.3	21.4	50.3	39.2
Sand vetch, roots,	12	1,560	231	32	189	4.4	1.3	2.5	3.5
Medium red clover, tops,	1	17,760	4,808	348	4,460	91.5	23.4	117.8	72.1
Medium red clover, roots,	1	12,600	2,630	278	2,352	52.2	16.2	38.8	26.2
White clover tops,	2	20,250	4,133	405	3,728	126.6	36.5	142.2	73.9
White clover, roots,	2	11,190	2,216	318	1,898	47.2	14.5	37.2	21.7
Alsike clover, tops,	3	15,690	3,956	347	3,609	85.5	28.6	125.2	65.0
Alsike clover, roots,	3	9,096	1,954	256	1,698	34.3	7.5	30.7	21.1
Crimson clover, tops,	5	12,492	3,402	363	3,039	82.6	20.7	73.6	66.7
Crimson clover, roots,	5	5,964	1,075	221	854	16.8	4.8	12.3	12.6
Crimson clover, tops,	9	33,900	4,893	417	4,476	132.5	28.8	123.1	95.6
Crimson clover, roots,	9	9,000	1,606	210	1,396	30.9	5.5	32.2	21.5
Crimson clover, tops,	10	13,320	1,629	145	1,484	41.6	9.9	34.9	36.2
Crimson clover, roots,	10	2,970	1,207	149	1,058	20.5	4.1	17.6	22.2
Timothy, tops,	4	7,920	3,344	180	3,164	26.1	16.2	54.9	17.1
Timothy, roots,	4	13,830	2,937	375	2,562	20.9	11.3	23.1	18.4

IV. POUNDS PER ACRE, TOPS AND ROOTS.

	Number of plot.	Total yield.	Dry matter.	Ash.	Organic matter.	Nitrogen.	Phosphoric acid.	Potash.	Lime.
Flat pea,	13	41.412	9,073	906	8,167	239.3	49.8	161.3	122.3
Canada field pea,	6	21,582	4,218	615	3,603	114.6	30.3	54.0	73.1
Spring vetch,	8	10,749	6,327	609	5,718	127.3	53.2	138.0	143.7
Sand vetch,	12	8,316	2,713	252	2,461	78.7	22.7	52.8	42.7
Medium red clover,	1	29,760	7,438	626	6,812	143.7	39.6	156.6	98.3
White clover,	2	31,440	6,349	723	5,626	173.8	51.0	179.4	95.6
Alsike clover,	3	24.786	5,910	603	5,307	119.8	36.1	155.9	86.1
Crimson clover,	5	18,456	4,477	584	3,893	99.4	25.5	85.9	79.3
Crimson clover,	9	42,900	6,499	627	5,872	163.4	34.3	155.3	117.1
Crimson clover,	10	16,290	2,836	294	2,542	62.1	14.0	52.5	58.4
Timothy.	4	21,750	6,281	555	5,726	47.0	27.5	78.0	35.5

Besides the fertilizing ingredients, the above tables show one other ingredient which is of great value to plant life in many instances, when it is added to the soil. This is the organic matter, or that part which goes to form the humus, that soft, spongy material which is abundant in all good soils. It plays an important part in the conservation of soil moisture, and other more complicated effects, both mechanical and chemical.

Table V shows the amount of sodium nitrate which it would be necessary to apply to an acre of ground to be equivalent to the nitrogen in the total crop, tops and roots, as shown in Table IV.

TABLE V. SODIUM NITRATE, POUNDS PER ACRE, EQUIVALENT TO THE NITROGEN CONTENT.

	Number of plot.	Tops.	Roots.	Total.
Flat pea,	13	1,089.4	406.3	1,495.7
Canada field pea,	6	675.0	41.3	716.3
Spring vetch,	8	749.4	46.3	795.7
Sand vetch,	12	464.4	27.5	491.9
Medium red clover,	1	571.9	326.3	898.2
White clover,	2	791.3	296.0	1,088.3
Alsike clover,	3	534.6	214.4	749.0
Crimson clover,	5	516.3	105.0	621.3
Crimson clover,	9	828.1	193.1	1,021.2
Crimson clover,	10	260.0	128.1	388.1

From a large number of experiments conducted with garden peas at the Storrs' School Agricultural Experiment Station, forty-one were selected which had either a "fair number" or a "large number" of root nodules at the time of cutting. Of the total nitrogen of these plants, the average percentage acquired from the atmosphere was 33.39. Judging from this average of the results of a large number of experiments, it seems fair to approximate that one-third of the nitrogen of a crop of healthy legumes is acquired from the atmosphere. The following table is calculated upon the above assumption, estimating the nitrogen at the same value as that in castor pomace, i. e., 12 cents per lb.

TABLE VI. VALUE OF ONE-THIRD OF THE NITROGEN AT TWELVE CENTS PER POUND.

	Number of plot.	Tops.	Roots.	Total.
Flat pea,	13	$6 97	$2 60	$9 57
Canada field pea,	6	4 32	26	4 58
Spring vetch,	8	4 80	30	5 10
Sand vetch,	12	2 97	18	3 15
Medium red clover,	1	3 66	2 09	5 75
White clover,	2	5 06	1 89	6 95
Alsike clover,	3	3 42	1 37	4 79
Crimson clover,	5	3 30	67	3 97
Crimson clover,	9	5 30	1 24	6 54
Crimson clover,	10	1 66	82	2 48

The above table shows the approximate money value of the nitrogen actually brought within reach of the agriculturist by the culture of any of these legumes. It must be remembered, however, that this statement is based upon the foregoing assumption and upon the results of this one experiment. A good crop of some one of these plants may be raised upon any piece of land that is at all adapted to agriculture, by the judicious application of a potash and phosphoric acid fertilizer. Whether the crop is plowed under as a green manure or whether it is fed to stock and the excrements, both solid and liquid, properly husbanded, the farmer has a stock of complete fertilizer of a high money value in return for the cheap, incomplete one which he applied originally.

It might be said of the medium red, white and alsike clover that, although their growth occupied a much longer period than the other legumes of the experiment, yet they would undoubtedly have yielded as large a crop had a quick-growing crop, such as wheat, barley or oats, occupied the plots with them for the first season. The weeds would have been kept down to a great extent by this procedure.

VARIETY TESTS OF WHEAT, OATS AND POTATOES.

BY GEORGE C. WATSON AND ENOS H. HESS.

SUMMARY.

1. The yield of grain from the different varieties of wheat varied greatly, which can only be accounted for through the difference in productiveness of the varieties.

2. A still greater variation in productiveness would be expected from the varieties now grown throughout the State.

3. In general, the yield of straw was proportionate to the yield of grain.

4. The different varieties of oats varied greatly in the production of grain.

5. The yield of straw did not follow the yield of grain so closely as was the case with the varieties of wheat.

6. The average of a six years' test of oats shows that one variety produced more than 45 per cent. more grain than another.

7. The average of a six years' test of potatoes shows a variation in production of more than 40 per cent.

8. The variation in single year's trials of potatoes was more than 250 per cent.

9. A comparison of the value of the different varieties of potatoes should not be based wholly on the yield of tubers.

DETAILS OF THE TESTS.

The primary object of these trials has been to determine, if possible, whether some of the many varieties of grain grown by farmers throughout the State were superior to other varieties in productiveness. It is well known that certain varieties in the hands of skillful men have given unusually large returns; but just how much of this increased yield is due to the superior variety in question and how much to the superior culture, fertilization, etc., is only a matter of conjecture.

In these trials the aim has been to give uniform conditions as related to culture, amount of seed per acre, fertilizer, etc., which should give fairly accurate results of the trials in comparing the productiveness of the various varieties under consideration.

In addition to this, an effort has been made to test new varieties as they are introduced by seedsmen, oftentimes with flaring announcements that are more or less deceptive. While the facilities of the Station have made it impossible to test all of the new varieties that are introduced from year to year, yet some of the more prominent and promising ones have been placed in the list and given the same treatment that older and tried varieties have received.

Besides the foregoing mentioned objects in making this test, minor considerations have been kept constantly in view, such as the liability to attack of fungous and insect enemies, vigor of plant, etc.

In time these observations may give favorable results, but for the present the productiveness of the varieties alone will be considered.

PLOTS.

The plots devoted to this use were one-twenty-eighth acre in size, 143 feet long and 11 feet wide, located side by side on adjoining sloping land inclined towards the east.

While these varieties were grown in plots, yet the objections which are oftentimes made to plot culture could hardly apply in this case, since the culture given to these varieties was such as would be given to a regular four years' rotation.

CONDITION OF SOIL.

The soil upon which these experiments have been conducted is a limestone clay loam of about eight inches in depth, through which fragments of flint are more or less scattered. It has good natural underdrainage and contains a fair supply of organic matter. The soil is fairly uniform in fertility and depth, but the depth of the subsoil varies greatly. In fertility the soil is without doubt somewhat above that of the average of the State.

The rotation followed is wheat, clover, potatoes and oats. The preparation of the soil, manure and time of seeding, culture and time of harvesting have been as nearly similar for all the plots of the different crops as possible.

Wheat.

The land used in the test of wheat varieties was plowed August 27th, to the depth of seven or eight inches, thoroughly pulverized and firmed. About forty pounds of phosphoric acid in the form of dissolved bone black and S. C. rock was applied per acre at the time of seeding and five tons of yard manure before the land was plowed. All the varieties were sown at the rate of six pecks per acre. The yields reported below are from careful weighings of the product of the different plots made at the time of threshing.

Yield of Wheat,—Varieties tested one year, 1897.

No.	Name of Variety.	Grain yield per acre (bushel, 60 pounds).	Straw yield per acre (pounds).	Weight per struck bushel (pounds).	Bearded or smooth chaff.	Color of grain, red, amber or white.
1	Mealy,	42.93	5,179	60.38	S.	R.
2	The Pool,	42.09	3,844	62.00	S.	R.
3	Fulcaster,	41.52	5,264	65.38	B.	R.
4	Royal Australian,	40.10	4,102	59.88	S.	W.
5	Fultz,	40.07	4,797	62.00	S.	R.
6	Deitz Longberry Red,	39.96	4,733	63.50	B.	R.
7	Jone's Square Head,	39.93	3,559	59.38	S.	W.
8	Extra Eary Oakley,	39.53	7,107	62.75	S.	R.
9	Theiss,	39.32	4,702	61.63	B.	R.
10	Forty Fold,	39.15	4,298	61.50	S.	W.
11	Rudy,	38.20	3,387	60.50	B.	R.
12	Ontario Wonder,	37.97	4,370	63.50	S.	A.
13	Canada Wonder,	37.48	3,983	60.88	B.	R.
14	Democrat,	37.42	4,525	63.38	B.	A.
15	Jone's Winter Fife,	36.64	3,364	62.88	S.	R.
16	Wyandotte Red,	36.47	3,628	64.50	S.	R.
17	Oregon,	36.32	3,082	63.38	S.	A.
18	Currell's Prolific,	36.30	3,916	64.50	S.	R.
19	Reliable,	36.10	4,855	62.82	B.	R.
20	Mediterranean,	35.86	5,325	64.38	B.	R.
21	Red Fultz,	35.72	4,641	63.75	S.	R.
22	Rochester Red,	35.28	4,243	60.25	S.	A.
23	Finley,	35.14	3,985	62.75	S.	R.
24	American Bronze,	33.87	3,575	61.63	S.	A.
25	German Emperor,	33.70	3,517	62.00	S.	R.
26	Valley,	33.55	4,633	63.38	B.	R.
27	Witter,	33.26	3,681	62.50	S.	R.
28	Egyptian,	33.00	3,559	62.75	S.	R.
29	Miama Valley,	32.92	4,257	63.13	B.	R.
30	Dawson's Golden Chaff,	32.92	3,285	58.50	S.	A.
31	Reliable Minnesota,	29.49	3,492	62.25	B.	A.
	Average of all varieties,	36.81	4,158	62.32		
	Average of 11 bearded varieties,	36.53	4,469	62.83		
	Average of 20 smooth varieties,	36.97	3,987	62.04		

The foregoing table gives a list of the varieties grown in 1897, arranged in order of grain production. The yield of straw follows quite closely the production of grain. While individual varieties show a marked difference in the proportional yield of grain and straw, yet the average of several varieties that were the most productive gives about the same proportion of grain to straw as does the average of several varieties that gave the poorest yield of grain.

It will be seen that there was a great difference in the yield of grain from the different varieties, one variety (Mealy) yielding 13.44 bushels per acre more than the variety (Reliable Minnesota), which gave the smallest yield, the one producing a trifle more than 45 per cent. more than the other.

This difference of yield is very great and can not be accounted for in any other way than the difference of productiveness of the two varieties. The question, however, is sometimes asked, "Will the average of several years' tests show similar results?" Probably not so marked, yet it has been found during six years' trial that the average of five of the most productive have produced 24.4* per cent. more than the average of five varieties that produced the least.

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* From Penn'a. Report 1895, p. 238.

This is a marked increase in production and should not be ignored. Whenever, by changing varieties, a farmer can increase the yield of grain nearly one-fourth, the subject is of too great importance to be dismissed without serious consideration. It is true that the subject of varieties has been much discussed, particularly in the younger Western states. In the Eastern and Middle states the general opinion is that variety tests are of comparatively little value. These simple tests, however, showing such a marked difference in the yield, indicate clearly that the subject is still an important one for the consideration of the farmers of Pennsylvania. The average yield of the bearded varieties does not differ materially from the average yield of the smooth varieties.

Yield of Wheat Varieties that have been tested 8 years, 1890-1897.

No.	Name of Variety	Grain yield per acre (bushel, 60 pounds).	Straw yield per acre (pounds).	Weight per struck bushel (pounds).	Bearded or smooth chaff.	Color of grain, red, amber or white.
1	Reliable,	32.70	3,980	62.83	B.	R.
2	Fulcaster,	32.10	4,199	63.12	B.	R.
3	Ontario Wonder,	31.19	3,385	61.69	S.	A.
4	Wyandotte Red,	30.66	3,172	63.53	S.	R.
5	Deitz Longberry Red,	30.64	3,859	62.87	B.	R.
6	Currell's Prolific,	30.49	3,462	63.01	S.	R.
7	Valley,	30.35	4,097	62.67	B.	R.
8	Mealy,	29.71	3,800	60.17	S.	R.
9	Fultz,	29.38	3,282	62.89	S.	R.
10	Theiss,	29.09	3,557	61.80	B.	R.
11	Mediterranean,	29.07	3,926	62.88	B.	R.
12	Red Fultz,	28.94	3,657	62.02	S.	R.
13	Extra Early Oakley,	28.88	3,329	62.59	S.	R.
14	Finley,	28.83	3,119	62.59	S.	R.
15	German Emperor,	28.69	3,323	62.14	S.	R.
16	Democrat,	28.60	3,589	62.71	B.	A.

The above table gives the average of yields of grain, straw and weight per bushel of grain of sixteen varieties of wheat that have been tested for eight years. After the test had been conducted for six years ten of the poorest were discarded on account of lack of available facilities for carrying on the test with so large a number of varieties. The ten discarded varieties were some of them quite weak and inferior. Some of them winter killed badly in severe seasons. It should be borne in mind, then, that the varieties given in this table represent the sixteen best varieties selected from twenty-six.

While this table shows quite a marked difference in the yield of grain and straw, yet the great difference is not seen that would have been shown had the ten poorer varieties been continued.

All of the varieties tested at this Station have been recommended as being especially desirable for the farmer to raise, so without doubt the difference in yield of the various varieties does not show so great a difference as would the same number of varieties selected at random from those now grown in Pennsylvania.

Yield of Wheat—Varieties that have been tested five years, 1893-1897.

No.	Name of Variety.	Grain yield per acre (bushel, 60 pounds).	Straw yield per acre (pounds).	Weight per struck bushel (pounds).	Bearded or smooth chaff.	Color of grain, red, amber or white.
1	Reliable,	31.85	3,808	63.06		
2	Royal Australian,	32.47	3,378	61.29	S.	W.
3	Jones Square Head,	31.27	3,074	60.12	S.	W.
4	The Pool,	31.25	3,111	62.81	S.	R.
5	Canada Wonder,	31.18	3,458	62.99	B.	R.
6	Rudy,	29.89	3,093	61.76	B.	R.
7	American Bronze,	29.08	3,110	62.26	S.	A.
8	Jones Winter Fife,	29.05	3,188	61.70	S.	R.

Varieties that have been tested four years, 1894-97.

No.	Name of Variety.	Grain yield per acre (bushel, 60 pounds).	Straw yield per acre (pounds).	Weight per struck bushel (pounds).	Bearded or smooth chaff.	Color of grain, red, amber or white.
1	Reliable,	33.06	3,640	62.99		
2	Oregon,	29.51	2,812	62.35	S.	A.
3	Miama Valley,	28.77	3,248	62.46	B.	R.
4	Egyptian,	28.48	3,182	62.66	S.	R.
5	Witter,	27.23	3,108	62.63	S.	R.

Varieties that have been tested two years, 1895-1897.

No.	Name of Variety.	Grain yield per acre (bushel 60 pounds).	Straw yield per acre (pounds).	Weight per struck bushel (pounds).	Bearded or smooth chaff.	Color of grain, red, amber or white.
1	Reliable,	30.03	2,859	63.66		
2	Forty Fold,	31.64	2,790	61.82	S.	W.
3	Rochester Red,	28.57	2,831	60.94	S.	A.
4	Reliable Minnesota,	26.14	2,428	62.24	B.	A.

The above table gives the average yield of varieties that have been tested for five years, those that have been tested for four years, and those that have been tested for but two years. In each one of these groups it will be noticed that there is quite a marked difference in the yield. For the sake of further comparison the average yield of the variety (Reliable) has been placed in each group. The average yield of this variety is for the same years that the other varieties of the group were tested. In two instances the average yield of the variety (Reliable) was not so great as the average of some others for the same time, notwithstanding the fact that the Reliable has given the largest average of any variety tested for eight years. In some years the yield of some of the poorer varieties has been as low as 11.52 bushels per acre, while the lowest yield in any one year of any one of the five best varieties tested for eight years was 22.59 bushels per acre.

Oats.

Seventeen varieties of oats were grown under as nearly similar conditions of soil, exposure, fertilizers, culture, etc., as possible, and the yields reported below are from careful weighings of the product of the different plots made at the time of threshing.

The plots were one-twenty-ninth acre in size; each plot was duplicated, and the figures given below represent the average of the two plots.

The rotation followed on the ground used is oats, wheat, clover and potatoes. It is the same ground on which the wheat and potato varieties were tested.

The land was plowed April 7th to the depth of 7 or 8 inches and thoroughly pulverized on the 21st and 22d by means of Acme spring-tooth and smoothing harrows. The varieties were sown with ordinary farm force feed grain drill at the rate of 8 pecks per acre, on April 22d. No fertilizer was applied.

Yield of Oats—Varieties tested one year (1897).

No.	Name of Variety.	Grain per acre (bushel, 32 pounds).	Straw per acre (pounds).	Weight per struck bushel (pounds).
1	Henderson's Clydesdale,	60.94	2,957	29.82
2	Improved American,	60.81	2,596	28.88
3	Buckbee's New Illinois,	60.66	3,569	30.07
4	Japan,	59.94	2,664	31.32
5	Baltic White,	59.65	2,672	32.25
6	German,	58.63	3,008	27.82
7	White Victoria,	58.37	2,861	30.07
8	Wide Awake,	58.09	2,652	29.69
9	Haggett's White,	56.94	2,907	31.83
10	Lincoln,	56.90	2,612	29.19
11	Scottish Chief,	56.84	2,577	28.76
12	Black Tartarian,	54.53	3,501	30.38
13	Everett's Superior Scotch,	54.53	2,763	34.63
14	Early Russian,	53.22	3,351	29.12
15	Negro Wonder,	52.43	2,504	28.83
16	Prize Taker,	48.34	2,739	27.75
17	Brancher,	47.62	3,796	30.12
	Average of 17 varieties,	56.38	2,908	30.63

The "Prize Taker" and "Everett's Superior Scotch" were ripe July 17th. All the other varieties ripened about July 22d, with the exceptions of the "Improved American," which ripened July 26th and the "Brancher," "Buckbee's New Illinois" and "Black Tartarian," which ripened July 29th.

In 1897 the "Henderson's Clydesdale" produced 60.94 bushels per acre, the largest yield of any variety tested. Following this variety in the order of their production are: "Improved American," 60.81; "Buckbee's New Illinois," 60.66; "Japan," 59.94; "Baltic White," 59.65; "German," 58.63; "White Victoria," 58.37, and "Wide Awake," 58.09.

It will be noticed that the "Prize Taker" is the best in weight, but in 1897 gave the smallest yield. The grain of this variety is very plump and would evidently sell somewhat better than the other varieties.

*Average yield of Oats—Varieties that have been tested 7 years, 1890-97.**

No.	Name of Variety.	Grain per acre (bushel, 32 pounds).	Straw per acre (pounds).	Weight per struck bushel (pounds).
1	Japan,	40.29	2,802	33.34
2	Improved American,	48.01	3,048	36.53
3	Baltic White,	46.27	2,748	33.72
4	German,	45.79	2,730	36.96
5	Scottish Chief,	45.47	2,417	32.38
6	Wide Awake,	42.92	2,369	33.66
7	Henderson's Clydesdale,	41.22	2,450	34.06
8	White Victoria,	41.18	2,527	33.74
9	Haggett's White,	41.14	2,475	35.28
10	Early Russian,	40.30	2,472	35.55

In the table showing the average for all the years tested, the varieties are arrayed in the order of their yields; the "Japan," as will be seen, leads the list with a yield of 48.01 bushels per acre. It is also the best in the yield of straw and second in the weight per bushel for the varieties tested seven years.

It is noticed that the proportional yield of straw to grain is not nearly so constant as was the case with wheat. There seems to be a tendency for the proportion of straw to increase as the yield of grain diminishes.

The largest proportion of straw was 2.17 pounds to one pound of grain. The lowest yield of straw was 1.66 pounds of straw to one pound of grain.

The five poorest varieties gave 1.95 pounds of straw to one pound of grain and the five best varieties 1.82 pounds of straw to one pound of grain.

*Average yield of Oats—Varieties that have been tested 6 years, 1890-95.**

No.	Name of Variety.	Grain per acre (bushel, 32 pounds).	Straw per acre (pounds).	Weight per struck bushel (pounds).
1	Japan,	46.02	3,125	37.58
2	Des Flanders,	36.30	2,680	31.44
3	Welcome,	35.92	2,366	37.41
4	Janne des Flanders,	35.19	2.401	32.83
5	White Bonanza,	34.67	2,031	36.99
6	White Wonder,	31.32	2,093	39.26

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*The crop of 1896 was injured by the army worm and is not included in the average.

*Aver age yield of Oats— Varieties that have been tested 2 years, 1895-97.**

No.	Name of Variety.	Grain per acre (bushel, 32 pounds).	Straw per acre (pounds).	Weight per struck bushel (pounds).
1	Japan,	50.62	2,881	32.51
2	Lincoln,	47.23	2,861	30.35
3	Negro Wonder,	44.87	2,667	30.63
4	Buckbee's New Illinois,	44.45	3,142	28.04
5	Everett's Superior Scotch,	41.19	2,768	34.91
6	Prize Taker,	38.18	2,287	33.94

The average yield of the "Japan" for 1895 and 1897 and 1890-1895, inclusive, is reported in another part of the table in order to serve as a comparison for the varieties tested during those years only. The last five varieties reported were not sown in 1897 on account of their small yield in previous years. By comparing the "Japan" and "White Wonder," the best and poorest varieties, we find that the "Japan" yielded 46.9 per cent. more grain and 49.3 per cent. more straw than the "White Wonder," the weight per bushel was 4.3 per cent. less. To a farmer growing 12 acres of oats, this would mean a difference of 176.4 bushels of grain and 6.19 tons of straw. Valueing the grain at 25 cents per bushel and the straw at $4.00 per ton, a difference in value of $68.87 is shown. It should be remembered that the varieties received the same kind of treatment in every respect and that such differences may occur on any farm and due wholly to the difference in productiveness of varieties.

Potatoes.

The same general plan of giving all the varieties the same treatment as regards fertilizers, cultivation, etc., was carried out with the potatoes, as in the case of wheat and oats.

Previous to plowing the sod in the spring, 18 tons of yard manure were applied. The ground was plowed 7 to 8 inches deep and cultivated four times with a spring tooth harrow.

The seed was cut to a single eye, except the pieces at the seed end, which had two or three eyes. The seed pieces were dropped 14 inches apart in rows three feet apart. An equal number of seed pieces were used for each plot. Last year some of the varieties were badly infected with scab. For this year's seed tubers were selected which had no scab visible. These tubers were then treated with a corrosive sublimate solution containing two ounces of sublimate to sixteen gallons of water.

The ground was marked with a corn marker and the rows opened with a plow. The seed pieces were covered with a hoe three to four inches deep. The planting was done May 17th and 18th.

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*Crop of 1896 omitted.

The ground was cultivated during the season often enough to destroy the weeds and keep the soil in a loose condition. A small amount of dirt was thrown up to the stalks on July 12th, after which no cultivation was given them.

Most of the varieties were slow in coming up and did not make a very good growth in June on account of cool weather. After the heavy rains in the middle part of June, the stalks grew quite rapidly for about three or four weeks, after which some of them began to mature. For the relative growth of stalks see table below. A variety was considered mature when the stalks were quite well dried.

The following table gives the yield of all the varieties grown in 1897. While there was a great difference in yield of the varieties per acre, the greatest yield being a little more than 250 per cent. more than the smallest yield, probably it will not be safe to make so strict a comparison of the yields of all the varieties as was made with wheat and oats, for the reason that there was a much greater difference in time of ripening than was the case with the cereals. The season may have been more favorable for those ripening at one time than another. Then, too, the time of ripening may give a variety a special value, aside from the quality of the tuber or yield per acre. This also would tend to give a less value to comparative yields.

Yield of Potatoes—Varieties tested one year, (1897).

No.	Name of Variety.	Total yield (bushels.)	Merchantable tubers (bushel, 56 pounds).	Unmerchantable tubers (bushels.)	Per cent. of large tubers.	Large, small or medium.	Rough, smooth or medium.
1	Great Divide,	221.9	207.1	14.8	93.34	M.	S.
2	Irish Daisy,	219.4	199.0	20.4	90.70	M.	S.
3	New White Peach Blow,	217.2	178.4	38.8	82.14	L.	M.
4	Carman No. 1,	215.9	207.5	8.4	96.11	L.	M.
5	Carman No. 3,	205.6	197.6	8.0	96.11	L.	S.
6	Washington,	196.9	191.5	5.4	97.26	L.	M.
7	Enormous,	196.1	190.7	5.4	97.25	L.	M.
8	Maule's Early thoroughbred,	187.2	174.7	12.5	93.38	S.	S.
9	Early Vaughan,	179.4	167.7	11.7	93.48	L.	M.
10	Freeman,	178.6	150.5	28.1	84.27	M.	S.
11	Delaware,	177.3	165.8	11.4	93.51	M.	S.
12	Late Puritan,	176.0	164.9	11.1	93.69	M.	S.
13	Maggie Murphy,	171.9	164.2	7.7	95.52	L.	R.
14	Seedling No. 2,	169.5	157.6	11.9	92.98	L.	S.
15	Stoneroad No. 2,	169.1	159.2	9.9	94.15	L.	M.
16	Country Gentleman,	168.7	149.0	19.7	88.32	S.	M.
17	Early Michigan,	166.4	153.4	13.0	92.19	L.	M.
18	Rose of Erin,	164.8	160.0	4.8	97.09	L.	M.
19	Quaker,	159.4	148.5	10.9	93.16	S.	M.
20	The Bovee,	157.1	138.8	18.3	88.35	M.	M.
21	Pennsylvania Best,	154.2	134.9	19.3	87.48	M.	S.
22	New Bovee Seedling,	150.8	119.0	31.8	78.91	S.	M.
23	Polaris,	147.4	138.1	9.3	93.69	S.	M.
24	Stoneroad No. 1,	147.2	138.0	9.2	93.75	L.	M.
25	Early Trumble,	134.7	116.7	18.0	86.64	M.	S.
26	Ben Harrison,	131.9	123.5	8.4	93.63	M.	M.
27	Early May,	124.5	108.0	16.5	86.75	M.	S.
28	Brownell's Winner,	122.8	108.6	14.2	88.44	L.	S.
29	Acme,	122.5	114.6	7.9	93.55	L.	M.
30	Northern Maine,	121.5	110.6	10.9	91.20	L.	S.
31	New Queen,	121.5	102.2	19.3	84.11	S.	S.
32	Early Everett,	119.1	101.9	17.2	85.57	M.	M.
33	Sir Walter Raleigh,	110.7	100.9	9.8	91.15	M.	M.
34	Early A,	99.4	75.3	24.1	75.76	S.	S.
35	Burpee's Surprise,	96.5	86.2	10.3	89.33	S.	M.
36	Early Maine,	80.7	61.2	19.5	75.83	S.	S.
37	World's Fair,	80.5	62.2	18.3	77.27	S.	S.
38	Early Ohio,	75.6	64.3	11.3	85.06	S.	S.
39	Extra Early,	66.3	60.3	6.0	90.95	L.	S.

Yield of Potatoes—Varieties tested one year (1897)—Continued.

No.	Name of Variety.	Growth of stalks.	Per cent. of stalks affected by earth blight.	Per cent. of stalks affected by late blight.	Date of maturity.		Number of days required to mature.	When dug.	
1	Great Divide,	95	5	45	Sept.	5	110	Sept.	9
2	Irish Daisy,	95	5	40	Sept.	8	114	Sept.	9
3	New White Peach Blow,	97	5	55	Sept.	5	110	Sept.	9
4	Carman No. 1,	96	5	50	Sept.	8	114	Sept.	9
5	Carman No. 2,	85	5	70	Sept.	5	111	Sept.	9
6	Washington,	98	5	40	Sept.	9	114	Sept.	9
7	Enormous,	100	5	65	Sept.	10	116	Sept.	10
8	Maule's Early Thoroughbred,	97	5	70	Aug.	27	101	Sept.	9
9	Early Vaughan,	75	10	90	Aug.	27	101	Aug.	30
10	Freeman,	72	15	95	Aug.	25	100	Aug.	30
11	Delaware,	85	10	70	Sept.	8	114	Sept.	9
12	Late Puritan,	85	10	70	Sept.	8	114	Sept.	9
13	Maggie Murphy,	98	5	85	Sept.	2	108	Sept.	9
14	Seedling No. 2,	90	5	35	Sept.	9	114	Sept.	10
15	Stoneroad No. 2,	75	5	70	Sept.	8	113	Sept.	9
16	Country Gentleman,	80	10	90	Aug.	28	102	Sept.	10
17	Early Michigan,	75	10	95	Aug.	21	95	Aug.	30
18	Rose of Erin,	95	5	95	Aug.	28	103	Sept.	9
19	Quaker,	95	10	75	Aug.	28	102	Sept.	9
20	The Bovee,	70	5	100	Aug.	21	95	Aug.	30
21	Pennsylvania Best,	78	10	95	Aug.	25	100	Aug.	30
22	New Bovee Seedling,	45	95	95	Aug.	21	96	Aug.	30
23	Polan's,	80	10	90	Aug.	25	99	Aug.	30
24	Stoneroad No. 1,	70	10	45	Sept.	8	113	Sept.	9
25	Early Trumble,	70	10	100	Aug.	21	95	Aug.	30
26	Ben Harrison,	50	80	95	Aug.	28	103	Sept.	9
27	Early May,	50	75	95	Aug.	21	95	Aug.	30
28	Brownell's Winner,	70	50	90	Aug.	29	103	Sept.	9
29	Acme,	43	88	100	Aug.	21	95	Aug.	30
30	Northern Maine,	75	15	75	Sept.	5	111	Sept.	9
31	New Queen,	40	95	98	Aug.	21	96	Aug.	30
32	Early Everett,	80	8	90	Aug.	28	103	Sept.	9
33	Sir Walter Raleigh,	73	5	75	Aug.	27	101	Aug.	30
34	Early A,	50	85	98	Aug.	25	100	Aug.	30
35	Burpee's Surprise,	40	85	90	Aug.	27	101	Sept.	9
36	Early Maine,	35	95	98	Aug.	25	99	Aug.	30
37	World's Fair,	97	5	85	Aug.	28	102	Sept.	10
38	Early Ohio,	40	95	98	Aug.	27	101	Aug.	30
39	Extra Early,	70	25	90	Aug.	25	99	Aug.	30

It will be noted that the variety (Great Divide) gave a yield of 221.9 bushels per acre, or a little more than three and one-third times as much as a variety known as Extra Early, that gave only 66.3 bushels per acre.

The time of ripening varied from 95 to 116 days, a difference of three weeks, and in a general way it may be said that the early varieties produced least, the medium ones more and the late maturing ones the largest yield of tubers.

While it is not possible to group the varieties into three divisions as early, medium and late maturing varieties, yet a somewhat arbitrary division into three groups may aid in comparing the yield as to the time of ripening.

Comparing yield of potatoes having different periods of ripening.

Period of Growth. Days.	Total Yield.			Growth of Stalk.
	Average.	Maximum.	Minimum.	
106 or more,	186	221.9	121.5	88.3
101 to 105 inclusive,	183	187.2	75.6	74.3
100 or less,	112.1	178.6	66.3	64.3

The growth of stalks was scored August 3d on the basis of 100 for the stalks covering all the ground between the rows, which were three feet apart.

Yield of Potatoes,—Varieties that have been tested 3 years, 1895-97.

No.	Name of Variety.	Total yield (56 pounds per bushel).	Merchantable tubers (bushels, per acre).	Unmerchantable tubers (bushels, per acre).	Per cent. of merchantable tubers.
1	Freeman,	280.1	248.8	31.3	88.86
2	New Bovee Seedling,	302.5	277.0	25.5	91.55
3	Carman No. 1,	290.4	277.3	13.2	95.49
4	Delaware,	274.6	259.1	15.4	90.71
5	Late Puritan,	273.7	259.3	14.4	94.74
6	Irish Daisy,	257.7	236.3	21.4	91.69
7	Rose of Erin,	257.4	250.8	6.6	97.44
8	Brownell's Winner,	236.3	221.0	15.3	93.57

Yield of Potatoes,—Varieties that have been tested 2 years, 1896-7.

No.	Name of Variety.	Total yield (56 pounds per bushel).	Merchantable tubers (bushels, per acre).	Unmerchantable tubers (bushels, per acre).	Per cent. chantable of mer- tubers.
1	Freeman,	255.3	230.7	24.6	90.37
2	Enormous,	338.5	333.1	5.4	98.40
3	Northern Maine,	265.8	251.6	14.1	94.66
4	Maggie Murphy,	253.4	244.5	8.9	96.49
5	Great Divide,	250.6	237.7	12.9	94.85
6	Early May,	250.0	227.7	22.3	91.08
7	Carman No. 3,	191.2	185.8	5.4	97.18

Yield of Potatoes,—Varieties that have been tested 4 years, 1894-'97.

No.	Name of Variety.	Merchantable tubers per acre (bushels, 56 pounds).	Unmerchantable tubers per acre). (bushels,	Total yield per acre (bushel).	Per cent. of merchantable tubers.
1	Freeman,	206.2	31.2	237.4	86.86
2	Early Everett,	202.7	27.6	230.3	88.02
3	Pennsylvania Best,	202.2	27.0	229.2	88.22
4	Ben Harrison,	209.1	18.8	227.9	91.75
5	New Queen,	203.5	23.6	227.1	89.57
6	Stoneroad No. 2,	195.6	22.0	217.6	89.89
7	Early A,	190.5	24.6	215.1	88.56
8	Stoneroad No. 1,	184.3	15.3	199.6	92.33
9	Early Maine,	169.6	28.2	197.8	85.74
10	Burpee's Surprise,	157.0	19.7	176.7	88.85
11	Early Ohio,	146.0	18.1	164.1	88.96

GENERAL FERTILIZER EXPERIMENTS.

BY ENOS H. HESS.

In the annual report for 1894, pp. 258-281, a summary of the results of twelve years' work, covering three complete four-year rotations, was presented, showing the gain or loss from the different combinations and amounts of fertilizer used.

During the season of 1897, the experiment was continued according to the original plan, as follows:

PLAN OF EXPERIMENT.

This experiment, embracing four tiers of thirty-six one-eighth acre plots each, was begun in 1881, for the purpose of studying:

(a) The comparative effect of single valuable ingredients of commercial fertilizers;

(b) The comparative effect of complete and incomplete fertilizers;

(c) The comparative effect of different forms of nitrogen;

(d) The comparative economic effect of different quantities of nitrogen;

(e) The effect of commercial fertilizers compared with barn-yard manure, lime and plaster;

(f) Effect of lime, ground limestone and plaster;

(g) The permanency of effect of the different fertilizers;

(h) Effect of various fertilizers on the growth of the different staple crops;

(i) Effect of the various fertilizers upon the relation of grain to straw;

(j) The effect of continuous cropping without manure.

The soil upon which these experiments have been conducted is a limestone, clay loam, of about eight inches in depth, through which fragments of flint are more or less thickly scattered. It has good, natural under-drainage and contains a fair supply of organic matter. The surface soil is fairly uniform in fertility and depth, but the subsoil varies greatly in depth.

The crops grown were of corn, oats, wheat and grass—mixture of clover and timothy—in a four-year rotation, occupying the land in the order named. The fertilizers were applied but twice during the four years required for a complete rotation, viz.: To the corn and to the wheat, with the exception of lime, on Plots 22 and 23, which has been applied to the corn only.

Prior to 1881, the land was used for miscellaneous field experiments, and since that time the occupation of the land is shown in the subjoined table:

Tier.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.	1889.
One, ..	Oats, ...	Wheat,	Grass, .	Corn, ...	Oats, ...	Wheat,	Grass, .	Corn, ...	Oats.
Two, ..	Corn, ...	Oats, ...	Wheat,	Grass, .	Corn, ...	Oats, ...	Wheat,	Grass .	Corn.
Three,	....	Corn, ...	Oats, ...	Wheat,	Grass, .	Corn, ...	Oats, ...	Wheat,	Grass.
Four, .	....	....	Corn, ...	Oats, ...	Wheat,	Grass, .	Corn ...	Oats, ...	Wheat.

	1890.	1891.	1892.	1893.	1894.	1895.	1896.	1897.
One, ...	Wheat, .	Grass, ..	Corn, ...	Oats, ...	Wheat, .	Grass, ..	Corn, ...	Oats.
Two, ...	Oats, ...	Wheat, .	Grass, ..	Corn, ...	Oats, ...	Wheat, .	Grass, ..	Corn.
Three, ...	Corn, ...	Oats, ...	Wheat, .	Grass, ..	Corn, ...	Oats, ...	Wheat, .	Grass.
Four, ...	Grass, ..	Corn, ...	Oats, ...	Wheat, .	Grass, ..	Corn, ...	Oats, ...	Wheat.

The valuable ingredients of plant food were furnished in the following forms:

Nitrogen.—Dried blood, nitrate of soda, and sulphate of ammonia.

Available Phosphoric Acid.—Dissolved bone-black, ground bone and blood.

Potash.—Muriate of potash.

Prior to 1888, the amount of valuable ingredients applied per plot was computed on the guaranteed composition of the fertilizers, which, in all cases, were high-grade goods, purchased from reputable manufacturers. Since that time, analyses of the materials used have been made each year, and the amount to be applied computed on the actual composition. These analyses have not shown a material variation from the seller's guarantee.

All fertilizers have been sown broadcast by hand after the land was plowed and the land then thoroughly cultivated and prepared for seeding. The barn-yard manure which has been spread and plowed under as in ordinary farm practice. The preparation of the soil, manner and time of seeding, culture, and time of harvesting have been made as nearly uniform for all plots, and for different years, as has been possible. The grass was sown with the wheat, in the fall, made up of timothy two parts and clover one part, at the rate of 8-10 quarts per acre and 4 quarts of clover in the spring.

RESULTS FOR 1897.

Corn.—Barn-yard manure was applied to Plots 16, 18, 20 and 22, April 8. Land plowed, April 23-26. Commercial fertilizers applied May 8, after the ground was cultivated once with spring-tooth harrow; the land was then harrowed twice with spring-tooth and once with spike-tooth harrow. Planted to a Dent variety, commonly grown in this locality, in hills three feet apart each way, three grains in a hill, May 11.

The corn came up quite uniformly, but, owing to cold weather and heavy rains in June, it did not grow well the first part of the season. On August 3, Plots 1, 2, 3, 4, 6, 13, 14, 23, 24, 33, 34 and 36 were in poor condition, while Plots 20 and 21 were looking very well. The corn was in bloom August 10-15, and matured about September 20. It made a fair growth, both of ears and stover, with the exception of a few of the poorest plots. Harvested and put on small shocks September 20-21. Husked and weighed October 13-14. Stover hauled to barn and weighed, November 13.

Oats.—All plots plowed seven to eight inches deep, March 31-April 1. Land thoroughly pulverized with spring-tooth and smoothing harrows April 19. April 19, seeded to Japan oats with a force feed drill, at the rate of two bushels per acre. Land rolled April 20. The oats on nearly all the plots made a very poor growth of straw, there being considerable rust, especially on Plot No. 23. Plots 21 and 35 had the best appearance when mature, but all of the plots were badly infected with smut. All the plots except Nos. 22, 23 and 34 were cut with a cradle July 24. Plots 22, 23 and 34, cut July 28. All tied and shocked July 30. On August 2, the plots were hauled to barn and threshed.

Wheat.—Yard manure was applied to Plots 16, 18, 20 and 22, August 4, 1896. All plots plowed eight inches deep, August 5-6. Commercial fertilizers applied broadcast on the plowed ground, after once cultivating. The seed bed was prepared by harrowing three times with spring-tooth harrow and rolling twice. All plots seeded to Dietz-Longberry red wheat, at the rate of two bushels per acre, with a force feed drill, September 2. More or less of the grain winter-killed, and on April 14 the plots presented any where from 53 per cent. of a perfect stand on the poorest (No. 4) to 83 per cent. on the best (No. 35). The straw made a very rank growth on most of the plots, but there was considerable rust. The wheat head was short but well filled out. Plot 11 had the largest stools. The plots were cut and shocked July 9-10, and hauled to the barn, weighed and threshed July 16.

Grass.—The grass was sown with the wheat, a mixture of two quarts timothy and one quart common red clover, at the rate of ten quarts per acre. On April 9, 1896, four quarts of clover seed was sown in addition to that sown the previous fall. The grass was injured comparatively little by the spring frosts, the stand on most of the plots being fair. All plots cut June 26 and hauled to barn and weighed June 28. The aftermath was cut August 16-17, and hauled to barn and weighed August 20.

YIELD PER ACRE OF DIFFERENT PLOTS, 1897.

Number of plot.	Kind of Fertilizer Applied.	Quanity of Fertilizers Applied per Acre.		Quantity of Valuable Ingredients Applied per Acre.			Corn—Tier III.			Oats—Tier II.			Wheat—Tier I.			Grass—Tier IV.
		Corn.	Wheat.	Nitrogen.	Phosphoric acid.	Potash.	Ears per acre—70 lbs. per bushel.	Stover per acre.	Number of stalks per acre.	Grain per acre—32 lbs. per bushel.	Straw per acre.	Weight per struck bushel.	Grain per acre—60 lbs. per bushel.	Straw per acre.	Weight per struck bushel.	Hay per acre.
							Bus.	Lbs.	No.	Bus.	Lbs.	Lbs.	Bus.	Lbs.	Lbs.	Lbs.
1	Nothing,	....	....	....	....	....	19.43	640	8,424	22.30	966	31.00	20.57	2,714	58.75	1,848
2	Dried blood,	218	250	24	....	....	22.86	1,040	8,992	27.56	1,294	30.88	22.22	3,102	58.13	1,252
3	Dissolved bone-black,	251	246	....	48	....	36.57	1,520	8,968	32.55	1,398	30.88	25.67	3,906	60.75	5,000
4	Muriate of potash,	202	201	....	....	100	28.57	1,440	9,296	30.45	1,186	31.18	17.63	2,150	59.38	2,384
5	Dried blood, Dissolved bone-black,	218 251	250 246	24	48	....	42.29	1,440	8,316	35.86	1,612	31.00	32.27	4,618	62.75	5,096
6	Dried blood, Muriate of potash,	218 202	250 201	24	....	100	35.43	1,760	9,448	30.02	1,200	30.75	21.30	2,824	58.75	3,120
7	Dissolved bone-black, Muriate of potash,	251 202	246 201	......	48	100	53.71	2,160	9,096	38.56	1,886	31.50	25.81	4,104	62.75	5,880
8	Nothing,	....	....	....	....	....	49.14	1,640	9,584	31.41	1,355	29.75	22.11	3,111	60.25	5,344
9	Dissolved bone-black, Muriate of potash, Dried blood,	251 202 218	246 201 250	24	48	100	56.57	2,400	9,344	41.28	1,879	31.63	30.09	5,552	62.63	5,704
10	Dissolved bone-black, Muriate of potash, Dried blood,	251 202 436	246 201 500	48	48	100	51.43	2,160	8,956	42.24	1,888	31.50	31.83	5,870	64.13	4,976
11	Dissolved bone black, Muriate of potash, Dried blood,	251 202 654	246 201 750	72	48	100	53.37	2,160	8,720	41.86	2,020	31.25	32.60	5,392	64.50	5,576
12	Ground bone, Muriate of potash, Dried blood,	207 202 198	194 201 237	30	48	100	52.29	2,200	9,248	42.33	1,906	31.75	26.15	3,708	63.63	5,920
13	Plaster,	320	320	....	....	....	24.57	1,160	7,000	27.63	1,076	28.63	17.34	2,172	59.63	3,176
14	Nothing,	....	....	....	....	....	34.29	1,440	8,812	28.16	1,059	29.88	15.88	1,970	60.38	2,876
15	Dissolved bone-black, Muriate of potash,	251 202	246 201	......	48	100	60.57	2,560	9,608	41.92	1,946	31.75	21.39	5,688	62.75	4,648
16	Yard manure,	12,000	12,000	....	....	....	58.86	2,536	8,928	43.80	2,038	31.50	26.72	4,222	63.00	3,896
17	Dissolved bone-black, Muriate of potash, Dried blood,	251 202 218	246 201 250	24	48	100	34.29	1,760	8,512	43.13	2,220	33.13	26.86	4,532	63.75	3,520
18	Yard manure,	16,000	16,000	....	....	....	46.86	2,160	9,004	46.10	1,973	31.63	28.99	4,641	64.50	5,496

19	Dissolved bone-black, …… Muriate of potash, …… Dried blood, ……	251 202 436	246 201 500	48	48	100	48.00	2,280	9,232	43.49	2,208	32.88	29.46	5,008	63.88	5,600
20	Yard manure, ……	20,000	20,000	……	……	……	51.43	2,400	9,584	45.44	2,146	31.25	29.34	4,972	64.50	5,120
21	Dissolved bone-black, …… Muriate of potash, …… Dried blood, ……	251 202 654	246 201 750	72	48	100	45.14	2,160	9,168	47.26	2,168	32.25	32.89	5,929	64.50	5,272
22	Yard manure, …… Lime, ……	20,000 4,000	2,000 ……	……	……	……	56.00	2,400	9,584	43.35	2,373	33.13	29.70	4,912	63.13	5,600
23	Lime, ……	4,000	……	……	……	……	19.43	1,120	7,952	24.60	1,498	31.38	27.72	3,822	62.00	2,120
24	Nothing, ……	……	……	……	……	……	18.06	1,000	7,912	31.31	1,158	30.13	25.91	3,488	61.75	2,488
25	Dissolved bone-black, …… Muriate of potash, ……	251 202	246 201	……	48	100	48.11	1,920	9,736	44.92	1,442	31.00	23.61	3,711	63.13	3,760
26	Dissolved bone-black, …… Muriate of potash, …… Nitrate of soda, ……	251 202 158	246 201 180	24	48	100	49.14	2,176	9,624	44.02	2,164	32.88	29.67	5,246	63.88	4,460
27	Dissolved bone-black, …… Muriate of potash, …… Nitrate of soda, ……	251 202 316	246 201 361	48	48	100	49.26	1,920	9,608	42.20	1,890	32.13	31.07	6,114	63.63	4,824
28	Dissolved bone-black, …… Muriate of potash, …… Nitrate of soda, ……	251 202 475	246 201 541	72	48	100	53.71	1,600	9,576	44.70	2,170	32.50	31.13	6,318	64.75	6,008
29	Dissolved bone-black, …… Muriate of potash, ……	251 202	246 201	……	48	100	41.71	1,680	9,208	41.28	1,999	33.38	21.88	3,410	63.25	4,420
30	Dissolved bone-black, …… Muriate of potash, …… Sulhpate of ammonia, ……	251 202 117	246 201 119	24	48	100	44.57	1,840	9,072	43.60	1,885	32.00	27.13	4,910	62.50	4,360
31	Dissolved bone-black, …… Muriate of potash, …… Sulphate of ammonia, ……	251 202 233	246 201 239	48	48	100	43.54	1,800	8,944	41.25	1,960	32.50	29.71	5,504	64.00	4,240
32	Dissolved bone-black, …… Muriate of potash, …… Sulphate of ammonia, ……	251 202 350	246 201 358	72	48	100	42.86	1,600	8,360	41.77	1,880	32.63	28.86	5,732	63.50	3,936
33	Plaster, ……	320	320	……	……	……	9.94	760	6,560	29.03	1,431	31.25	27.44	3,804	61.13	3,832
34	Ground limestone, ……	4,000	4,000	……	……	……	29.71	1,280	7,648	30.29	1,448	31.75	29.69	4,304	62.13	3,072
35	Ground bone, …… Muriate of potash, …… Dried blood, ……	207 202 198	194 201 237	30	48	100	56.00	2,320	9,112	48.14	2,340	32.50	29.65	4,948	63.63	5,200
36	Nothing, ……	……	……	……	……	……	19.43	920	7,704	34.35	1,422	30.25	23.48	3,442	63.75	3,340

EFFECT OF DIFFERENT COMBINATIONS AND DIFFERENT AMOUNTS OF FERTILIZERS, 1897.

Number.	Kind of Fertilizer Applied.	Quantity of Single Ingredients per Acre.		Quantity of Valuable Ingredients per Acre.			Number of plots.	Corn—Tier III.			Oats—Tier II.			Wheat—Tier I.			Grass—Tier IV.
		Corn.	Wheat.	Nitrogen.	Phosphoric acid.	Potash.		Ears per acre—70 lbs. per bushel.	Stover per acre.	Number of stalks per acre.	Grain per acre—32 lbs. per bushel.	Straw per acre.	Weight per bushel.	Grain per acre—60 lbs. per bushel.	Straw per acre.	Weight per bushel.	Hay per acre.
								Bus.	Lbs.	No.	Bus.	Lbs.	Lbs.	Bus.	Lbs.	Lbs.	Lbs.
1	Nothing,	....	....	....	....	....	5	28.07	1,128	8,387	29.50	1,192	30.20	28.78	2,945	60.98	3,179
2	Dried blood,	218	250	24	....	....	1	22.86	1,040	8,992	27.56	1,294	30.88	29.63	3,102	58.13	1,252
3	Dissolved bone-black,	251	246	....	48	....	1	36.57	1,520	8,968	32.56	1,398	30.88	34.23	3,906	60.75	5,000
4	Muriate of potash,	202	201	24	....	100	1	28.57	1,440	9,296	30.44	1,186	31.13	23.50	2,150	59.38	2,384
5	Dried blood, Dissolved bone-black,	218 251	250 246	24	48	....	1	42.29	1,440	8,816	35.88	1,612	31.00	43.03	4,618	62.75	5,096
6	Dried blood, Muriate of potash,	218 202	250 201	24	....	100	1	35.43	1,760	9,448	30.00	1,200	30.75	28.40	2,824	58.75	3,120
7	Dissolved bone-black, Muriate of potash,	251 202	246 201	24	48	100	4	51.03	2,080	9,412	40.91	1,818	31.91	30.90	4,228	63.97	4,677
8	Dissolved bone-black) Muriate of potash, Dried blood,	251 202 218	246 201 250	24	48	100	2	45.43	2,080	8,928	42.22	2,050	32.38	37.97	5,042	63.19	4,612
9	Dissolved bone-black, Muriate of potash, Dried blood,	251 202 436	246 201 500	48	48	100	2	49.71	2,220	9,094	46.00	2,048	32.19	40.87	5,427	64.01	5,288
10	Dissolved bone-black, Muriate of potash, Dried blood,	251 202 654	246 201 750	72	48	100	2	49.26	2,160	8,944	44.25	2,094	31.75	43.67	5,661	64.50	5,424
11	Dissolved bone-black, Muriate of potash, Nitrate of soda,	251 202 158	246 201 180	24	48	100	1	49.14	2,176	9,624	44.00	2,164	32.88	39.57	5,246	63.88	4,460
12	Dissolved bone-black, Muriate of potash, Nitrate of soda,	251 202 318	246 201 361	48	48	100	1	49.26	1,920	9,608	42.19	1,890	32.13	41.43	6,114	63.63	4,824
13	Dissolved bone-black, Muriate of potash, Nitrate of soda,	251 202 475	246 201 541	72	48	100	1	53.71	1,600	9,576	44.69	2,170	32.50	41.50	6,318	64.75	6,008
14	Dissolved bone-black, Muriate of potash, Sulphate of ammonia,	251 202 117	246 201 118	24	48	100	1	44.57	1,840	9,072	43.60	1,885	32.00	36.17	4,910	62.50	4,360

	Dissolved bone-black,	251	246															
15	Muriate of potash,	202	201	48	48	100	1	43.54	1,800	8,944	41.25	1,960	32.50	39.60	5,504	64.00	4,240
	Sulphate of ammonia,	233	239															
	Dissolved bone-black,	251	246															
16	Muriate of potash,	202	201	72	48	100	1	42.86	1,600	8,360	41.75	1,880	32.63	38.47	5,732	63.50	3,936
	Sulphate of ammonia,	350	358															
17	Yard manure,	12,000	12,000	...	...	...	1	58.86	2,536	8,928	43.81	2,038	31.50	35.63	4,222	63.00	3,896
18	Yard manure,	16,000	16,000	...	...	...	1	46.86	2,160	9,004	46.10	1,973	31.63	33.65	4,641	64.50	5,496
19	Yard manure,	20,000	20,000	...	...	...	1	51.43	2,400	9,584	45.44	2,146	31.25	39.13	4,972	64.50	5,120
20	Yard manure,	12,000	...	...	...	...	1	56.00	2,400	9,584	43.34	2,373	33.13	39.60	4,912	63.13	5,600
	Lime,	4,000	12,000															
21	Lime,	4,000	...	...	...	...	1	19.43	1,120	7,952	24.59	1,493	31.38	36.97	3,822	62.00	2,120
22	Ground limestone,	4,000	4,000	...	...	...	1	29.71	1,280	7,648	30.28	1,448	31.75	39.60	4,304	62.13	3,072
23	Plaster,	320	320	...	...	...	2	17.26	960	6,780	28.34	1,254	29.94	29.87	2,988	60.38	3,504
	Ground bone,	207	194															
24	Muriate of potash,	202	201	30	48	100	2	54.14	2,260	9,180	45.06	2,123	32.13	37.20	4,338	63.63	5,560
	Dried blood,	198	237															
	Average yield of plots receiving complete fertilizers containing:																	
	Dried blood,	...	...	...	...	...	6	48.13	2,153	8,989	43.22	2.064	33.11	40.83	5,380	63.90	5,108
	Nitrate of soda,	...	...	...	...	...	3	50.66	1,899	9,603	43.63	2,075	32.50	40.85	5,898	64.09	5,097
	Sulphate of ammonia,	...	...	...	...	...	3	43.66	1,747	8,792	42.19	1,908	32.38	38.08	5,382	63.33	4,179
	Nitrogen, 24 lbs. per acre,	...	...	...	...	...	4	46.14	2,044	9,138	43.00	2,037	32.41	37.92	5,060	63.19	4,511
	Nitrogen, 48 lbs. per acre,	...	...	...	...	...	4	48.06	2,040	9,185	42.31	1,987	32.25	40.68	5,623	63.91	4,910
	Nitrogen, 72 lbs. per acre,	...	...	...	...	...	4	48.77	1,880	8,956	43.91	2,060	32.16	41.82	5,843	64.31	5,198
	Yard manure,	...	...	...	...	...	4	53.29	2,374	9,275	44.69	2,133	31.88	39.92	4,688	63.78	5,028

EXCHANGES.

The publications of this Station are sent regularly to the leading agricultural papers of the country, as well as to all newspapers in the State. The following agricultural and local papers have been sent to the Station regularly during a whole or part of the year, in exchange for its publications:

Agricultural Epitomist, Indianapolis, Ind.
American Agriculturist, New York, N. Y.
American Grange Bulletin and Scientific Farmer, Cincinnati, O.
American Horse Breeder, Boston, Mass.
American Sheep Breeder and Wool Grower, Chicago, Ill.
American Swine Herd, Chicago, Ill.
Breeders' Gazette, Chicago, Ill.
California Cultivator and Poultry Keeper, Los Angeles, Cal.
Chicago Produce, Chicago, Ill.
Connecticut Farmer, Hartford, Conn.
Creamery Gazette, Des Moines, Ia.
Creamery Journal, Waterloo, Ia.
Dairy World, Chicago, Ill.
Drainage Journal, Indianapolis, Ind.
Elgin Dairy Report, Elgin, Ill.
Farm Journal, Philadelphia, Pa.
Farm News, Springfield, O.
Farm and Fireside, Springfield, O.
Farm and Home, Springfield, Mass.
Farmer's Friend, Mechanicsburg, Pa.
Farmer's Guide, Huntingdon, Ind.
Farmers' Home, Dayton, O.
Farmers' Review, Chicago, Ill.
Farming, Toronto, Canada.
Farming World, Clinton, Ia.
Howard's Dairyman, Ft. Atkinson, Wis.
Holstein Friesian Register, Brattleboro, Vt.
Home Monthly, Pittsburgh, Pa.
Homestead, Des Moines, Ia.
Hospodar, Omaha, Neb.
Indiana Farmer, Indianapolis, Ind.
Irrigation Age, Chicago, Ill.
Jersey Bulletin, Indianapolis, Ind.

La Laiterie, Paris, France.
Louisiana Planter, New Orleans, La.
Market Basket, Philadelphia, Pa.
Market Gardener, Minneapolis, Minn.
Mark Lane Express, London, England.
Mirror and Farmer, Manchester, N. H.
Montana Fruit Grower, Missoula, Mont.
National Stockman and Farmer, Pittsburg, Pa.
New England Farmer, Boston, Mass.
New York Farmer, Port Jervis, N. J.
New York Produce Review and American Creameryman, New York.
Oregon Agriculturist, Portland, Ore.
Our Grange Homes, Boston, Mass.
Pacific Coast Dairyman, Tacoma, Wash.
Pennsylvania Farmer, Meadville, Pa.
Poultry Monthly, Albany, N. Y.
Practical Dairyman, Chatham, N. Y.
Practical Farmer, Philadelphia, Pa.
Rural New Yorker, New York, N. Y.
Southern Planter, Richmond, Va.
Sugar, London, England.
Sugar Beet, Philadelphia, Pa.
Swine Breeders' Journal, Indianapolis, Ind.
Utah Church and Farm, Salt Lake City, Utah.
Veterinary Record, London, England.
Wallace's Farmer, Des Moines, Ia.
West Virginia Farm Review, Charleston, W. Va.
Wool Grower and Sheep Breeder.
Wool Record, New York, N. Y.
Baltimore Weekly Sun, Baltimore, Md.
Bedford Inquirer, Bedford, Pa.
Bucks County Intelligencer, Doylestown, Pa.
Central News, Perkasie, Pa.
Clarion Democrat, Clarion, Pa.
Delaware County Democrat, Chester, Pa.
Detroit Free Press, Detroit, Mich.
Downingtown Archive, Downingtown, Pa.
Erie Weekly Herald, Erie, Pa.
Johnstown Weekly Democrat, Johnstown, Pa.
Juniata Herald, Mifflintown, Pa.
Leechburg Advance, Leechburg, Pa.
Monitor, Clearfield, Pa.
New York Weekly Witness, New York, N. Y.
Patron, Bellefonte, Pa.
Pennsylvania Quarterly Grange Trade Bulletin, Centre Hall, Pa.

Public Ledger, Philadelphia, Pa.
Quakertown Free Press, Quakertown, Pa.
Reading Adler (German), Reading, Pa.
Reading Weekly News, Reading, Pa.
Review, Norristown, Pa.
Sharpsville Advertiser, Sharpsville, Pa.
Slatington News, Slatington, Pa.
The Sun, Quarryville, Pa.
Village Record, West Chester, Pa.

DISTRIBUTION OF SEEDS OF VARIETIES OF FARM CROPS.

Many inquiries having been received from persons living in various parts of the State, who desire to test or purchase seeds of some of the varieties grown here, we take this means of stating that the Station does not make any free distribution of seeds. We give in our reports the source from which we obtain seed, and farmers can usually obtain the same by addressing the parties named. We endeavor to grow each variety true to name and use seed from reliable persons or dealers. The small surplus of each variety remaining after securing our seed for the following season is kept, and we will supply parties desiring the same, as long as our supply lasts, charging a moderate price which hardly covers the expense of keeping seed pure and preparing it for shipment.

LIST OF STATION PUBLICATIONS.

Reports.

1887,* 1888,* 1889,* 1890,* 1891,* 1892, 1893,* 1894,* 1895,* 1896.*

Bulletins.

*Bulletin No. 1.—Soiling Crops.

*Bulletin No. 2.—Experiments with Phosphates.

*Bulletin No. 3.—Composition and Digestibility of Corn Stover.

*Bulletin No. 4.—Seed Germinations.

*Bulletin No. 5.—Digestibility of Soiling Rye.

*Bulletin No. 6.—Tests of Varieties, 1888.

*Bulletin No. 7.—Tests of Varieties, 1888.

*Bulletin No. 8.—Systematic Testing of New Varieties, Germination Tests.

*Bulletin No. 9.—Digestibility of Corn Fodder and Silage.

*Bulletin No. 10.—Should Farmers Raise Their Own Vegetable Seeds? Notes on New Varieties of Vegetables. Tests of Agricultural Varieties, 1889.

*Bulletin No. 11.—Indian Corn as a Grain and Forage Crop.

*Bulletin No. 12.—Simple Methods of Determining Milk Fat.

*Bulletin No. 13.—Black Knot on Plums. A Few Ornamental Plants.

*Bulletin No. 14.—Tests of Varieties of Vegetables for 1890.

*Bulletin No. 15.—Influence of Variety and Rate of Seeding on Yield of Ensilage Corn.

*Bulletin No. 16.—Culture of the Chestnut for Fruit. Analysis of Several Varieties of Chestnuts.

*Bulletin No. 17.—The Value of Cotton Seed Meal as compared with Bran for the Production of Butter.

*Bulletin No. 18.—Notes on New and Old Varieties of Orchard Fruits and Small Fruits.

*Bulletin No. 19.—Information on Spraying Fruits.

Bulletin No. 20.—Tests of Dairy Apparatus.

*Bulletin No. 21.—The Koch Test for Tuberculosis.

*Bulletin No. 22.—Tests of Dairy Apparatus.

Bulletin No. 23.—Forest Fires. Experience with Evergreens in Pennsylvania.

*Bulletin No. 24.—Influence of Quantity of Food upon Economy of Milk and Butter Production.

*Bulletin No. 25.—Small Fruits in 1893.

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*Reports and Bulletins marked thus (*) are out of print and cannot be supplied

*Bulletin No. 26.—Mangels and Sugar Beets vs. Silage. Yield, Cost and Feeding Value.

*Bulletin No. 27.—Tests of Cream Separators.

Bulletin No. 28.—Cotton Seed Feed for Dairy Cows.

Bulletin No. 29.—Tuberculosis in Cattle.

*Bulletin No. 30.—Tobacco Experiments.

Bulletin No. 31.—Report of the Director for 1894.

*Bulletin No. 32.—Small Fruits in 1894.

*Bulletin No. 33.—Directions for Using the Babcock Milk Test.

*Bulletin No. 34.—A Phosphate Deposit in Juniata County.

*Bulletin No. 35.—A Soil Test with Fertilizers.

*Bulletin No. 36.—Chestnut Culture for Fruit.

Bulletin No. 37.—The Peach Industry in Pennsylvania.

Bulletin No. 38.—A Test of Hand Separators.

*Bulletin No. 39.—Variety Tests of Wheat, Oats and Potatoes.

Bulletin No. 40.—The Sugar Beet in Pennsylvania.

*Bulletin No. 41.—Tests of Dairy Feeds.

*Bulletin No. 42.—Maintenance Ration of Cattle (Scientific Bulletin).

Bulletin No. 43.—Apples in Pennsylvania.

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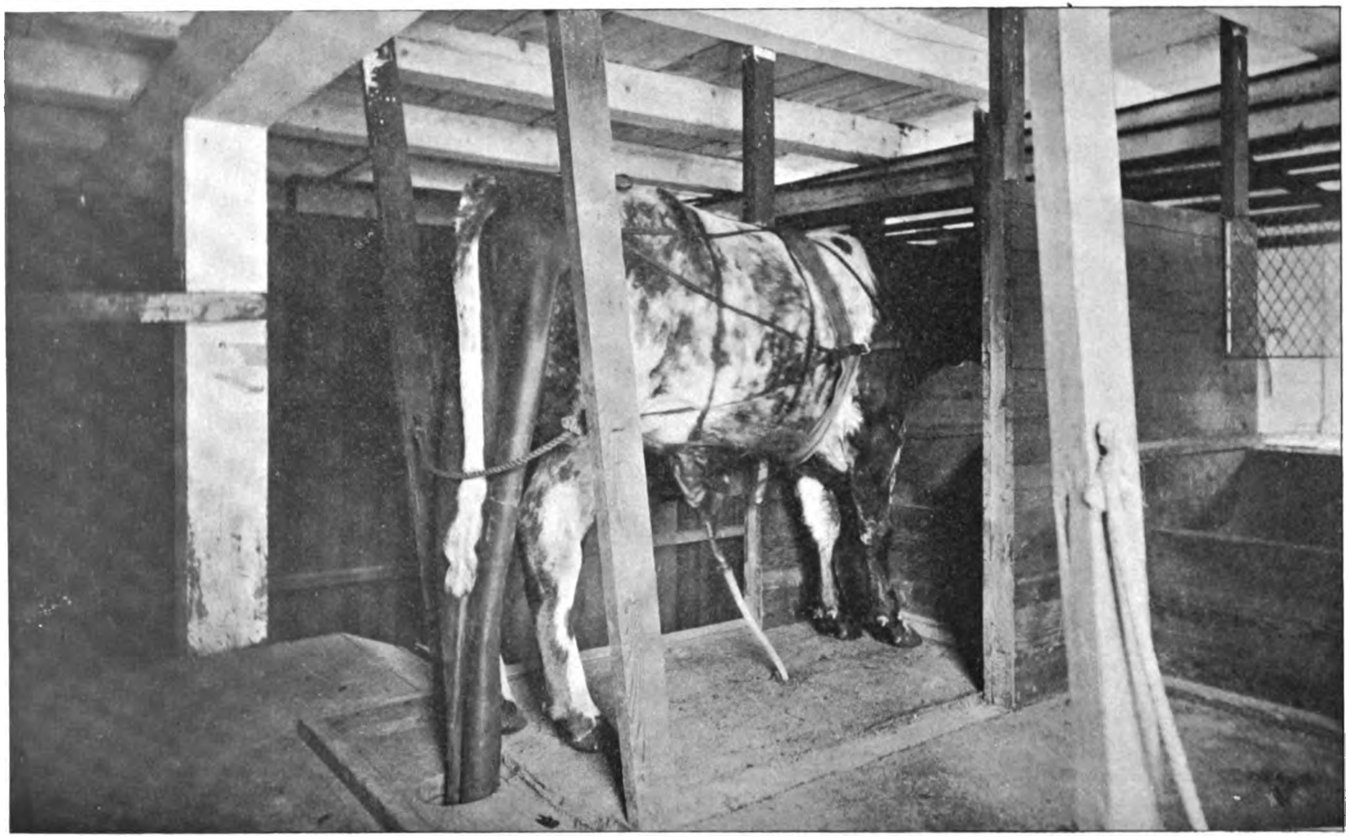
*Reports and Bulletins marked thus (*) are out of print and cannot be supplied.



Apparatus for Digestion Experiments.

INVESTIGATIONS

ON

THE MAINTENANCE RATION OF CATTLE,

BY

HENRY PRENTISS ARMSBY, Ph. D.

Supplement to the Annual Report of the Agricultural Experiment Station for 1897-8.

CONTENTS.

Page.
Review of Literature, ... 166
Experiments at this Station, ... 183
  Experiments of 1892-3, ... 183
    Animals, ... 183
    General Plan, ... 183
    Methods, ... 183
   Experiment I, ... 184
     Digestibility, ... 186
     Proteid Metabolism, ... 188
     Live Weights, ... 188
   Experiment II, ... 195
     Digestibility, ... 195
     Proteid Metabolism, ... 198
     Live Weights, ... 198
  Experiments of 1893-4, ... 202
    Animals, ... 202
    General Plan, ... 203
    Methods, ... 203
    Feeds Used, ... 203
   Experiment III, ... 204
     Digestibility, ... 204
     Proteid Metabolism, ... 207
     Energy of Excreta, ... 208
     Live Weights, ... 209
   Experiment IV, ... 213
     Digestibility, ... 213
     Proteid Metabolism, ... 216
     Live Weights, ... 217
   Experiment V, ... 219
     Digestibility, ... 219
     Proteid Metabolism, ... 222
     Energy of Excreta, ... 222
     Live Weights, ... 223
  Experiments of 1894-5, ... 226
   Preliminary Feeding, ... 226
   Experiment VI, ... 231
     Appliances, ... 232
     Methods, ... 233
       Weighing and Sampling, ... 233
       Analytical Methods, ... 235
     Daily Records and Averages, ... 235
     Temperature of Stable, ... 235
     Dry Matter and Nitrogen Eaten, ... 236
     Digestibility, ... 237

Page.
Special Digestion Period, ... 238
Daily Rations, ... 243
Proteid Metabolism, ... 243
Energy of Urine, ... 244
Live Weight, ... 245
Experiment VII, ... 247
Dry Matter and Nitrogen Eaten, ... 250
Digestibility, ... 250
Special Digestion Period, ... 251
Daily Rations, ... 257
Proteid Metabolism, ... 258
Energy of Urine, ... 258
Live Weights, ... 259
Experiments of 1896-7, ... 261
Experiment VIII, ... 261
Animals, ... 261
Appliances and Methods, ... 261
Weighing and Sampling, ... 261
Sampling of Excreta, ... 263
Temperature of Stable, ... 263
Rations Fed, ... 264
First Digestion Period, ... 266
Second Digestion Period, ... 271
Daily Rations, ... 276
Proteid Metabolism, ... 277
Energy of Excreta, ... 278
Live Weight, ... 280
Discussion of Results, ... 282
Digestibility of the Rations, ... 282
Individual Differences, ... 282
Variations in Digestibility, ... 287
Computed Indigestible Matter, ... 288
Percentage Digestibility, ... 291
Probable Errors, ... 293
Errors in Weighing, ... 293
Errors in Determination of Air-Dry Matter of Feces, .. 293
Errors in Determination of Air-Dry Matter of Hay, ... 295
Probable Error of Nitrogen, ... 296
Probable Errors of co-efficients, ... 296
Live Weight as a Measure of Nutritive Effect, ... 299
The Balance of Energy, ... 303
The Energy of the Digested Food, ... 303
The Energy of the Urine, ... 306
Energy of Hydrocarbons, ... 309
Available Energy of Food, ... 309
The Maintenance Ration, ... 313
The Quantity of Food, ... 313
Comparison with Earlier Results, ... 315
Relative Value of Coarse Fodder and Grain, ... 317
The Minimum of Proteids, ... 322

PLATES.

The Digestion Stalls, ... Frontispiece.

Plate I, Experiments of 1892-3; Live-Weight.

Plate II,
Plate III, Experiments of 1893-4, Live Weight and Water Consumed.
Plate IV,

Plate V,
Plate VI, Preliminary Feeding, 1894-5, Live Weight and Water Consumed.
Plate VII,

Plate VIII, Experiments VI and VII, 1894-5, Air-Dry Matter and Nitrogen
Plate IX, Digested.

Plate X,
Plate XI, Experiments VI and VII, 1894-5, Live Weight and Water Consumed.
Plate XII,

Plate XIII,
Plate XIV, Experiment VIII, 1896-7, Live Weight and Water Consumed.
Plate XV,

Plate XVI, Observed and Computed Indigestible Matter of Hay, Experiments VI and VII.

Plate XVII, Percentage Digestibility computed from Results of overlapping Ten-Day Averages, Experiments VI and VII.

THE MAINTENANCE RATION OF CATTLE.

BY HENRY PRENTISS ARMSBY.

For a scientific study of the relations between the food of domestic animals and the resulting products, a knowledge of the amount of food required for the simple maintenance of the animals under experiment is an indispensable condition, as was long ago pointed out by Henneberg.

It is of course a truism that the demands of the organism for energy to replace that lost in the form of heat by radiation, conduction and in the excreta must be supplied before any normal and continued production, either of material products or of work, is possible; yet this fundamental fact seems to have been strangely overlooked in most feeding experiments, and attention has been directed to the ratio of products to *total* food. A certain degree of justification for this practice exists, it is true, in the case of purely practical experiments, designed to test the economic value of certain rations or feeding stuffs, since the feeder must pay for the maintenance food of his animals as well as for that which serves for productive purposes. Very slight reflection is sufficient to show, however, that the results of such a comparison of product with total food are essentially empirical. In any rational study of nutrition—that is, in any study directed toward the elucidation of the scientific principles involved—it is plainly inadmissible to attempt to establish general laws by a comparison of the food with one of its effects, viz., production, while ignoring entirely its other effect, viz., maintenance. When we consider further that under ordinary circumstances from one-third to one-half or more of the total food of domestic animals is required for maintenance, we readily see that the neglect of this constant factor cannot fail to greatly obscure if not to entirely conceal the laws governing the disposal of excess food by the animal.

Another unfortunate result of the neglect of this important factor in the study of animal nutrition has been that comparatively little attention has been paid to the determination of this fundamental quantity. In the case of cattle, in particular, up to a very recent date our knowledge of their maintenance requirements has been based chiefly upon six experiments made by Henneberg and Stohmann in

1858. The results of these experiments, and the feeding standard derived from them by Wolff, entered into the literature of the subject and passed current comparatively unquestioned for fully two decades.

At about the time when Wolff's feeding standards began to come into use in the United States, the results of several more or less carefully conducted experiments were published which seemed to show that the accepted standard for the maintenance of cattle was too high, and more or less discussion of the subject took place in the agricultural press, but the investigations were chiefly directed toward other ends, and, aside from sporadic references, this phase of the matter failed to receive further attention.

A subsequent study of these experiments and a consideration of their apparent irreconcilability with Henneberg and Stohmann's results, led the writer to consider further investigation of the question desirable and the experiments described below were instituted in the winter of 1892-3 and continued during 1893-4, 1894-5 and 1896-7.

For the general plan of the experiments and for the discussion of the results, the writer is responsible. The details of the stable work of the experiments, including the weighing, collection and sampling of food and excreta, the weighing of the animals and the temperature observations, were in charge of Mr. Wm. H. Caldwell, Assistant Agriculturist of the Station, during the years 1892-3 and 1893-4, of Mr. E. H. Hess during 1894-5, and of Mr. R. J. Weld during 1896-7. The chemical analyses of food and excreta were performed, under the direction of Dr. Wm. Frear, Chemist of the Station, by Messrs. J. W. Fields, W. S. Sweetser, J. A. Fries, M. E. McDonnell, M. S. McDowell and C. W. Norris, Assistant Chemists. The calorimetric determinations in food and excreta were made in the laboratory of the Storr's School Experiment Station, at Middletown, Conn., by the courtesy of its director, Dr. W. O. Atwater, under the immediate supervision of the Chemist of the Station, Dr. C. D. Woods, on samples furnished by us.

During the progress of the experiments appeared Kellner's report upon the very elaborate investigations on the same subject made at the Moeckern Experiment Station by himself and by G. Kühn and his associates* with more complete appliances than were at the command of this Station. While these investigations cover the ground very fully, it has nevertheless seemed advisable, in view of the theoretical importance of the subject, to put on record the results reached here and also to attempt to bring together in a single publication the available data upon the maintenance ration of cattle.

REVIEW OF LITERATURE.

As already noted, the earliest exact investigations on the maintenance of cattle were made by Henneberg and Stohmann† at the Weende Experiment Station, on two mature draft oxen, weighing respectively about 575 and 516 kilograms. These animals were fed in three successive periods various rations in amounts sufficient to maintain their live weight with little or no change.

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*Landw. Vers. Stat. 44, 257; 47, 275.

The periods, exclusive of transition periods, were from one to two months long. The animals stood in the special form of stall first devised by Henneberg and Stohmann for digestion experiments, and during the last three to four weeks of each period the feces and urine of the animals were collected and weighed. In the case of Ox I in Period I, the original ration had to be modified, and both the total feeding period and the collection of excreta covered but eleven days. During the last three days of each period, samples of the excreta were taken for analysis. Deducting small uneaten residues, the exact rations consumed during the last three days, computed per 500 kilograms live weight, were as shown below. The amounts for the whole feeding period, however, were not materially different.

Rations per 500 kgs. Live Weight.

	Ox I.	Ox II.
Period 1.	March 17 to 27: Oat straw, 6.36 kgs. Mangels, 23.90 kgs.	March 4 to 27: Clover hay, 9.77 kgs.
Period 2.	March 28 to May 21: Oat straw, 6.29 kgs. Mangels, 12.78 kgs. Rape cake, 0.50 kgs.	April 4 to May 21: Oat straw, 6.50 kgs. Clover hay, 1.86 kgs. Rape cake, 0.28 kgs.
Period 3.	June 19 to July 15: Oat straw, 7.09 kgs. Clover Hay, 1.81 kgs. Rape cake, 0.26 kgs.	May 28 to July 15: Rye straw, 6.65 kgs. Clover hay, 1.90 kgs. Rape cake, 0.29 kgs.

The animals were usually weighed at intervals of seven days, although occasionally more frequently, and invariably immediately before and after the final three days of each period. Subsequent experience has demonstrated the great uncertainty attaching to single weights of cattle and more frequent (if possible daily) weighing would now be regarded as essential in such experiments, but it would be palpably unjust to criticise the experiments of forty years ago in the light of to-day's knowledge. The graphic chart of the weights shows, as was to be expected, considerable fluctuations. A marked gain took place during the first half of Period 2, so sudden and rapid as to suggest an accumulation of food or water in the alimentary canal rather than an actual fattening. Aside from this there seems to be a tendency to a loss rather than a gain. The weights taken during the periods in which the excreta were collected were:

---

†Beiträge zur Begründung einer rationellen Fütterung der Weiderkaüer, Heft I, 17-188.

Live Weights.

	Ox I. Kilograms.	Ox II. Kilograms.
PERIOD I. Average temperature, 50.7 degrees F.		
March 5,	....	504.5
March 12,	....	506.0
March 19,	576.5	497.5
March 20,	....	504.5
March 23,	573.3	501.5
March 26,	576.8	501.5
PERIOD II. Average temperature, 61.7 degrees F.		
April 23,	595.5	533.5
April 30,	592.5	537.5
May 7,	593.5	536.0
May 14,	590.0	535.5
May 18,	586.5	536.0
May 21,	587.0	534.5
PERIOD III. Average temperature, 68.7 degrees F.		
June 19,	591.5	537.0
June 25,	588.5	523.0
July 2,	589.0	523.5
July 9,	585.3	521.3
July 13,	568.0	528.0
July 16,	573.5	524.0

The results of the last three days of each period afford data for computing the digestibility of the rations and also the proteid metabolism. In the original, the digestibility is computed directly from the weighings and analyses of the last three days and also as corrected by applying the analytical results for these three days to the average amount of feces excreted during the whole time that they were collected. On the basis of these corrected results, the amounts digested per day and 500 kilograms live weight were as given below. No determinations of fat were made, except in the rape cake, so that the amount of this ingredient cannot be stated separately.

Digested per Day and 500 Kilograms Live Weight.

	Dry matter. Grms.	Ash. Grms.	Organic matter. Grms.	Crude proteids. Grms.	Crude fiber. Grms.	Nitrogen-free extract and fat. Grms.
OX I.						
Period 1,	4,700	275	4,425	178	4,247	
Period 2,	4,000	195	3,805	259	1,200	2,346
Period 3,	4,350	215	4,135	209	1,700	2,226
OX II.						
Period 1,	4,250	0	4,250	422	1,300	2,528
Period 2,	4,050	165	3,885	278	1,600	2,007
Period 3,	4,100	105	3,995	247	1,950	1,798
Average,	4,242	159	4,083	266	1,550	2,481
					3,817	

The total proteid metabolism, expressed in terms of nitrogen, was as follows:

Proteid Metabolism per Day and 500 Kilograms Live Weight.

	Nitrogen of food. Grms.	Nitrogen of feces. Grms.	Nitrogen digested. Grms.	Nitrogen of urine. Grms.	Gain or loss. Grms.
OX I.					
Period 1,	69.5	41.0	28.5	24.5	+4.0
Period 2,	73.0	31.5	41.5	20.5	+21.0
Period 3,	73.0	39.5	33.5	22.5	+11.0
OX II.					
Period 1,	156.0	88.5	67.5	82.5	—15.0
Period 2,	79.0	34.5	44.5	25.0	+19.5
Period 3,	79.0	39.5	39.5	44.5	—5.0

It is evident from the last column of the table that the collection of the urine must have been imperfect, since we can hardly suppose that on some of these rations from one-third to one-half the digested proteids was actually stored up in the body while in other periods, under apparently similar circumstances nearly as great a loss occurred.

The live weights of the animals, as given above, indicate that the rations were approximately maintenance rations. Assuming this to be the case, we can, by the use of the usual factors (4.1 Cal. per gram of proteids or carbohydrates and 9.4 Cal. per gram of fat), express the rations approximately in terms of energy, as in the table below. It is interesting to note in this connection that Henneberg and Sthomann also employed this method of expression. They obtained their results, however, in another way, viz., by computation from the amount of oxygen consumed, this in its turn being computed from the elementary composition of the food and the visible excreta on the assumption of no gain or loss of carbon or hydrogen by the animals. Their results have been included in the table, and likewise the computed energy of the digestible matter of the rations after deducting the amount of proteids (N x 6.25) apparently retained in the body or adding that apparently lost from the body. It should be noted that in all the results computed from the rations fed the fat has of necessity been included with the carbohydrates and reckoned at 4.1 Cal. per gram, and that the calculated figures are therefore slightly too low.

Computed Energy per 500 Kilograms Live Weight.

	Computed from Rations.		By Henneberg & Stohmann's method.
	From digestible matter.	Corrected for gain or loss of proteids by animal.	
OX I.			
Period 1,	18,148 Cal.	18,040 Cal.	16,830 Cal.
Period 2,	15,601 Cal.	15,063 Cal.	14,190 Cal.
Period 3,	16,954 Cal.	16,671 Cal.	16,170 Cal.
OX II.			
Period 1,	17,425 Cal.	17,810 Cal.	16,006 Cal.
Period 2,	15,929 Cal.	15,428 Cal.	14,685 Cal.
Period 3,	16,280 Cal.	16,507 Cal.	16,170 Cal.
Average,	16,723 Cal.	16,587 Cal.	15,675 Cal.

As the general result of these experiments, it may be stated that the animals were apparently maintained by a daily ration containing about 16,600 Cal. of available energy, while variations in the amount of crude proteids (N x 6.25) from less than 200 grms. to over 400 grms. showed no marked effect upon the nutrition of the animals.

The temperature of the stable in these experiments was considerably higher than it is usually practicable to keep it in winter, and in view of this fact Wolff[*] increased these amounts somewhat in formulating the maintenance ration for winter feeding which has since become generally current. That ration, expressed in the same terms as have been used above, is:

Digestible proteids, 350 grms.
Available energy, 18,540 Cal.

In 1879 Sanborn[†] called in question, if not the correctness of these results, at least their applicability to American conditions. In a publication of the previous year[‡] he stated that the steers under experiment gained materially "on less food than the Germans have found necessary to maintain existence without gain or loss," referring in this statement, however, to a requirement of 3 per cent. of live weight daily of hay, quoted as the result of German experiments but without reference to its source.

Scarcely any details as to the methods followed in these earlier experiments are given, but the main results are stated as follows, the feed being coarse timothy hay:

> "Fed three two-year-old steers 82 days; consumed 5065 lbs; per cent. of live weight daily 1.9; gain 136 lbs."
>
> "Two three-year-old steers consumed, in 30 days, 1636 lbs. of hay; per cent. of daily consumption 2.2 per cent. of live weight; gain of steers, 94 lbs."

Assuming the hay to have had the average composition of American timothy hay, as compiled by Jenkins & Winton[||] and that its digestibility is represented by the coefficients compiled by Jordan,[**] and computing the actual live weight from the percentages stated, we have the following as the approximate composition of the rations:

---

[*] Fütterungslehre, 2d ed., pp. 132 and 196.

[†] Farm Experiments at the New Hampshire College of Agriculture, pp. 8, 18 and 25-26.

[‡] Farm Experiments, College Farm, N. H., p. 10.

[||] U. S. Dept. Agric., Office of Exp. Stations, Bulletin 11.

[**] Experiment Station Record, 6, 7.

Estimated Rations.

	Per Day and Head.		Per 500 Kgs., Live Weight.	
	Two-year-olds. Average weight 1,084 lbs.	Three-year-olds. Average weight 1,240 lbs.	Two-year-olds.	Three-year-olds.
Total dry matter,..	17.88 lbs.	23.67 lbs.	8,246 grms.	9.545 grms.
Digestible:				
Proteids, ...	0.60 lbs.	0.79 lbs.	277 grms.	319 grms.
Carbohydrates, ..	9.00 lbs.	11.92 lbs.	4,151 grms.	4,807 grms.
Fat, ...	0.29 lbs.	0.38 lbs.	134 grms.	153 grms.
Total, ...	9.89 lbs.	13.09 lbs.	4,562 grms.	5,279 grms.
Computed energy,	19,081 Cal.	25,253 Cal.	19,415 Cal.	22,454 Cal.

In both cases, therefore, the ration, although less than 3 per cent. of the live weight, is in excess of both Henneberg and Stohmann's average and Wolff's standard.

The conclusions advanced in 1879 appear to have more direct reference to Wolff's standard for maintenance. The experiments consist of a comparison of early-cut with late-cut timothy hay, a test of "meal versus hay," and several experiments in which mixed rations were fed.

In the first of these experiments,* two lots of two steers each were fed respectively on early-cut and late-cut timothy hay for 14 days; the rations of the two lots were then exchanged and the feeding continued for 14 days longer. The results reported were as follows per day and head:

	Average live weight. Lbs.	Hay eaten. Lbs.	Gain. Lbs.
LOT 1, ...	1,022	....	....
Early-cut hay, ...	....	20.36	1.46
Late-cut hay, ...	....	20.89	1.18
LOT 2, ...	1,023	....	....
Early-cut hay, ...	....	25.21	1.43
Late-cut hay, ...	....	20.22	2.11

Laboratory-dry samples of both lots of hay were analyzed at the Connecticut Agricultural Experiment Station,† the results, reduced to average water-content, being:

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*Loc. cit., p. 5.

†Report, 1879, p. 79.

Percentage Composition.

	Early-cut hay.	Late-cut hay.
Water,	14.30	14.30
Ash,	4.10	3.90
Proteids,	5.82	4.75
Non-proteids,	0.38	0.55
Crude fiber,	25.30	27.50
Nitrogen-free extract,	48.10	47.20
Ether extract,	2.00	1.80
	100.00	100.00

Applying Jordan's* average coefficients of digestibility for American timothy hay, viz:

Crude proteids,	49
Crude fiber,	53
Nitrogen free extract,	63
Ether extract,	57

to the above results, we find the daily rations per 500 kgs. live weight to have been approximately the following:

Estimated Rations.

	Total dry matter. Grms.	Digestible.				Computed available energy. Cal.
		Proteids. Grms.	Carbohydrates. Grms.	Ether extract. Grms.	Total. Grms.	
LOT 1.						
Early-cut hay,	8,536	303	4,354	114	4,771	20,166
Late-cut hay,	8,759	266	4,529	110	4,905	20,693
LOT 2.						
Early-cut hay,	10,588	375	5,386	140	5,901	24,936
Late-cut hay,	8,510	258	4,400	107	4,765	20,105

In the second series of experiments‡ we find the following data per day and head for the lots fed on hay alone:

	Average live weight. Lbs.	Hay eaten. Lbs.	Gain. Lbs.	Length of experiment. Days.
Lot 2 (p. 13),	1,135	27.8	0.36	42
Lot 2 (p. 15),	1,032.5	22.3	—0.11	56
Lot 1 (p. 15),	1,034	24.3	1.01	56

The hay appears to have been timothy. Assuming, as before, its content of digestible matter to have been that of the average American product, we find the daily rations per 500 kgs. live weight to have been approximately as follows:

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*Experiment Station Record, 6, 7.

†Loc. cit., pp. 13 and 15.

Estimated Rations.

	Total dry matter. Grms.	Digestible.				Computed available energy. Cal.
		Proteids. Grms.	Carbo-hydrates. Grms.	Ether extract. Grms.	Total. Grms.	
Lot 2 (p. 13), ...	10,630	355	5,354	171	5,880	25,014
Lot 2 (p. 15), ...	9,374	313	4,720	151	5,184	22,055
Lot 1 (p. 15), ...	10,200	341	5,135	164	5,640	23,993

Of the third series of experiments* on mixed rations, Nos. 3 and 4 are those in which, according to Sanborn's computations, the smallest amounts of digestible matter were fed, and in which, also, the smallest gains were made. In these experiments, extending over seventy days, the following rations were fed per day and head:

	Straw.	Corn meal.	Meat scrap.	Gain per day.
Lot 3, ...	17.3 lbs.	2.5 lbs.	....	0.26 lbs.
Lot 4	16.5 lbs.	0.5 lbs.	2.0 lbs.	0.58 lbs.

The meat scrap contained 9.37 per cent. of moisture and 51.09 per cent. of total proteids (N x 6.25). The weights of the animals are not given. Assuming them to average 1,000 lbs., and assuming further that the straw and the corn meal had the average composition and digestibility shown in the compilations already referred to, the rations contained approximately the following amounts of nutrients per day and 500 kgs. live weight.

Estimated Rations.

	Total dry matter. Grms.	Digestible.				Computed available energy. Cal.
		Proteids. Grms.	Carbo-hydrates. Grms.	Ether extract. Grms.	Total. Grms.	
Lot 3, ...	8,916	190	4,590	119	4,899	20,717
Lot 4, ...	8,610	640	3,782	81	4,503	18,892

In the table below, the main results of Sanborn's experiments have been brought together for convenience of comparison:

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*Loc. cit., pp. 20 and 25.

Estimated Rations per Day and 500 Kilograms Live Weight.

	Length of experiment. Days.	Digestible proteids. Grms.	Available energy. Cal.	Gain per day. Kgs.
1878.				
Two-year-olds,	82	277	19,415	0.38
Three-year-olds,	80	319	22,454	0.36
1879.				
Lot 1. Early-cut hay,	14	303	20,166	0.71
Lot 1. Late-cut hay,	14	266	20,693	0.58
Lot 2. Early-cut hay,	14	275	24,963	0.70
Lot 2. Late-cut hay,	14	258	20,106	1.52
Lot 2 (p. 13),	42	355	25,014	0.16
Lot 2 (p. 15),	56	312	22,055	—0.05
Lot 1 (p. 15),	56	341	23,993	0.49
Lot 3,	70	190	20,717	0.43
Lot 4,	70	640	18,892	0.29
Henneberg & Stohmann's average,	....	200-400	16,000	....
Wolff's standard,	....	250	18,540	....

In every case the total ration exceeds Henneberg and Stohmann's average, the excess ranging from 13.80 per cent. to 50.69 per cent., and in only two cases does it even approximate Wolff's standard. A similar comparison of some of Sanborn's results was made by Johnson* in 1879, with substantially the same general result.

On the other hand, it is true, a considerable gain in weight was observed in most cases. In view, however, of the well-known uncertainties attaching to the interpretation of live weight, as well as of the meagreness of the experimental data reported and the consequent approximate nature of the above computations, no conclusions seem warranted as to whether the amount of food in excess of either Henneberg & Stohmann's average or Wolff's standard was sufficient to account for the observed gain. Certainly, however, the results fail, except in a single instance, to sustain Sanborn's claim that ordinary gains were made on rations corresponding to Wolff's standard for maintenance.

During several subsequent years, Sanborn carried on feeding experiments with steers. In most or all of these later experiments the feeding stuffs used were analyzed, and their digestibility computed by the use of "German," (probably Wolff's) coefficients. The results were published chiefly in the Mirror and Farmer, of Manchester, N. H., the reports being popular in character and to a large degree lacking in details. The following selection from those accessible to the writer includes all cases in which the ration was not materially above Wolff's standard for maintenance, the amounts of digestible matter being those computed by Sanborn and the available energy having been computed by the writer.

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*Rep. Conn. Agr. Exp. Station, 1879, p. 100.

Per Day and 500 Kilograms Live Weight.

Date of Publication.	Length of experiment. Days.	Digestible.				Computed available energy. Cal.	Gain or loss in weight. Kgs.
		Proteids. Grms.	Carbohydrates. Grms.	Ether extract. Grms.	Total. Grms.		
	49	315	3,700	130	4,145	17,683	—0.15
	49	175	2,825	60	3,060	12,864	+0.30
September 4, 1881,	49	295	3,485	130	3,910	16,720	+0.49
	49	665	2,670	165	3,500	15,225	+0.83
	49	665	3,020	190	3,875	16,894	+0.45
	40	164	2,706	55	2,925	12,253	—0.08
	40	343	3,675	130	4,148	17,695	+0.36
	40	719	2,872	156	3,747	16,188	+0.27
	40	395	3,106	142	3,643	15,689	+0.28
	40	777	2,659	280	3,716	16,449	+0.84
October 13, 1881,	40	582	2,974	171	3,727	16,185	+0.42
	29	176	2,900	58	3,134	13,156	—0.02
	29	918	3,074	116	4,108	17,457	+0.24
	29	475	3,424	160	4,059	17,490	+0.21
	29	889	2,869	362	4,120	18,810	+0.66
	29	716	2,943	197	3,856	16,854	+0.63
	27	230	3,713	82	4,025	16,937	—0.50
August 10, 1882,	39	1,005	3,130	345	4,480	20,197	+0.29
Average,	....	528	3,097	163	3,788	16,371	+0.31

While it is true that relatively little weight attaches to a single experiment of this sort, the general result of them all, in spite of irregularities in single cases, appears to substantiate Sanborn's contention that ordinary gains were obtained on rations less in amount than Wolff's standard, and, it may be added, in many cases less than Henneberg and Stohmann's average.

Subsequent experiments by Sanborn at the Missouri Agricultural College* gave results confirmatory of those previously obtained by him and summarized above. As computed by the author, the essential results were as follows:

Estimated Rations per Day and 1000 Pounds Live Weight.

Organic matter. Lbs.	Digestible.				Gain in weight. Lbs.
	Proteids. Lbs.	Carbohydrates. Lbs.	Ether extract. Lbs.	Total. Lbs.	
13.00	1.8	5.6	0.18	7.58	0.55
12.28	....	....	....	7.23	0.38
11.46	....	....	....	7.29	0.04

Assuming the digestible matter of the second and third experiments to have the heat value of the carbohydrates, the above rations contained approximately the following amounts of available energy per 500 kgs. live weight:

No. 1, ...	15,530 Cal.
No. 2, ...	14,820 Cal.
No. 3, ...	14,950 Cal.

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*The Missouri State Agricultural Farm; Bulletin No. 2. Synopsis of experiments made by J. W. Sanborn at the Missouri Experiment Station, p. 12.

Sanborn's results led Caldwell* to undertake further experiments in this direction. Three steers, one three years old and the others two years old, were fed a ration intended to correspond with Wolff's standard, but subsequent analyses of the feeding stuffs used showed the latter to be of better quality than was supposed. The ration per day and 1,000 lbs. live weight consisted of:

Corn stalks,	14.2 lbs.
Clover hay,	3.8 lbs.
Corn meal,	1.9 lbs.
Malt sprouts,	0.84 lbs.

and is computed by the author to have contained

Dry matter,	17.60 lbs.
Digestible proteids,	0.80 lbs.
Digestible non-nitrogenous matter,	8.03 lbs.
Nutritive ratio,	1:10

After a preliminary period of two weeks, the feeding was continued for six weeks, the animals being weighed daily. The average weights of the lot for each week were:

Average Weights of Lot.

1st week,	2,535 lbs.
2nd week,	2,571 lbs.
3rd week,	2,590 lbs.
4th week,	2,633 lbs.
5th week,	2,685 lbs.
6th week,	2,773 lbs
Gain in 5 weeks,	238 lbs.
Gain per day and 1,000 lbs. live weight,	2.68 lbs.

In a second experiment by Caldwell,† four steers were put on an approximate maintenance ration, calculated on the basis of Wolff's standard and from analyses of the fodder used. The ration, which was fed for sixty days, consisted per day and head of:

Hay,	4.25 lbs.
Corn stalks,	13.00 lbs.
Corn meal,	1.75 lbs.
Cotton-seed meal,	0.56 lbs.

and was computed to contain per day and 1,000 lbs. live weight:

Dry matter,	15.30 lbs.
Digestible proteids,	0.68 lbs.
Digestible carbohydrates and fat,	8.60 lbs.

The gain in live weight, computed from the difference between the averages of the first four and last four weighings, amounted to 1.14 pounds per day and 1,000 lbs. live weight.

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*Report Cornell University Exp. Station, 1882-3, p. 18.

†Rep. Cornell University Exp. Station, 1883-4, p. 20.

Putting the above results into the same form as those already given, and adding the computed energy of the rations, we have the following:

Per Day and 500 Kgs. Live Weight.

	Total dry matter. Grms.	Digestible.			Computed available energy. Cal.	Gain in weight. Kgs.
		Proteids. Grms.	Carbohydrates. Grms.	Total. Grms.		
1882-3,	8,800	400	4,015	4,415	18,102	1.34
1883-4,	7,650	340	4,300	4,650	19,024	0.57

In both experiments a considerable gain resulted from the use of rations slightly or not at all greater than Wolff's maintenance standard.

In 1887, the writer, in conjunction with Frear and Patterson,* carried on a digestion experiment at this Station which incidentally afforded some data regarding the subject under consideration. Two steers were fed upon corn stover for 35 days, during the last 20 of which the feces were collected. During these twenty days, the average amounts digested per day were:

	Steer 1.	Steer 2.
Ash,	0.36 lbs.	0.34 lbs.
Proteids,	0.27 lbs.	0.25 lbs.
Non-proteids,	0.12 lbs.	0.12 lbs.
Crude fiber,	1.95 lbs	1.89 lbs.
Nitrogen-free extract,	3.55 lbs.	3.39 lbs.
Ether extract,	0.13 lbs.	0.12 lbs.
Dry matter,	6.38 lbs.	6.11 lbs.

During the last 29 days of the feeding, the amounts of dry matter actually eaten were:

Steer No. 1,	9.96 lbs.
Steer No. 2,	10.03 lbs.

this being the full amount which the animals could be induced to consume. Applying the average coefficients obtained in the twenty days digestion trial, we obtain the following as the amounts digested per day during the 29 days:

	Steer 1.	Steer 2.
Ash,	0.34 lbs.	0.33 lbs.
Proteids,	0.25 lbs.	0.24 lbs.
Non-proteids,	0.11 lbs.	0.11 lbs.
Crude fiber,	2.02 lbs.	2.05 lbs.
Nitrogen-free extract,	3.38 lbs.	3.35 lbs.
Ether extract,	0.12 lbs.	0.12 lbs.
Dry matter,	6.22 lbs.	6.20 lbs.

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*Agricultural Science, 2, 149.

The animals were weighed daily, immediately before watering. The average weights for the first five and last five days of the 29 were:

Live Weights.

	Steer 1.	Steer 2.
December 3-7, inclusive,	899 lbs.	986 lbs.
December 27-31, inclusive,	903 lbs.	970 lbs.
Gain or loss in 24 days,	+4 lbs.	—16 lbs.
Per day,	+0.17 lbs.	—0.67 lbs.

Expressing the results in the same form as in previous cases, they become:

Rations per Day and 500 Kgs. Live Weight.

	Total dry matter. Grms.	Digestible.				Computed available energy. Cal.	Gain. Kgs.
		Proteids. Grms.	Carbohydrates. Grms.	Ether extract. Grms.	Total. Grms.		
Steer 1,	5,540	200	3,004	67	3,271	13,766	+0.09
Steer 2,	5,085	178	2,739	61	2,978	12,533	—0.34

While the results of a short experiment, in which the effects of the feeding are judged of solely from the live weight, must be accepted with considerable reserve, yet the above figures point in the same direction as those already cited. The stable temperature was not recorded, but was probably about 50 degrees F.

Alvord* has reported an experiment in which two Ayrshire heifers, well advanced in pregnancy, were fed for 64 days an average of about 40 lbs. per day of silage, consisting of corn, sorghum and soja bean. The animals averaged about 625 lbs. each and gained slightly during the trial. From analyses (not given) of the silage, the author computes the daily ration to have contained:

Digestible proteids,	0.91 lbs.
Digestible carbohydrates,	8.08 lbs.
Digestible ether extract,	0.39 lbs.
	9.38 lbs.

Calculated per 500 kgs. live-weight, this is equivalent to:

Digestible proteids,	728 grms.
Digestible carbohydrates,	6,465 grms.
Digestible ether extract,	312 grms.
	7,505 grms.
Computed available energy,	32,424 Cal.

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*Maryland Experiment Station, Bul. 8, p. 12.

If we make the reduction to the standard weight of 500 kgs. on the assumption that the maintenance ration is proportional to the surface rather than to the weight of the animal (i.e., to the two-thirds power of the weight), as explained on a subsequent page, we still have a total of 27,717 Cal., or 50 per cent. more than Wolff's standard. Nothing appears in the record of the experiment to account for this extraordinary and exceptional result.

The respiration experiments made at the Moeckern Experiment Station by G. Kühn and his associates and reported after Kühn's death by Kellner,* together with some later work by Kellner himself,† constitute by far the most complete investigations upon this subject yet reported.‡ These experiments, in which substantially a maintenance ration was consumed, were made with coarse fodder exclusively (meadow or clover hay and oat straw), and the experiments include both determinations of digestibility and of the total metabolism of nitrogen and carbon (including the excretion of methan). They were made with the greatest care and by the most approved methods. After a long preliminary feeding, the feces and urine were collected for from 14 to 17 days, and during this time five (or in two cases four) respiration trials, each covering 24 hours, were made. The designations and average live weights of the animals and the rations fed were:

	Feed per day and head.	Average live weight. Kgs.	Average temperature of stable. °C.
KÜHN'S EXPERIMENTS.			
Ox II. Period 1,	10 kgs. meadow hay,	632	12.0
Ox III. Period 1,	4.5 kgs. clover hay, 4.5 kgs. oat straw,	632	14.7
Ox IV. Period 1.a.,	The same,	631	14.7
Ox IV. Period 1.b.,	The same,	623	14.9
Ox V. Period 1,	9 kgs. meadow hay,	602	14.7
Ox VI. Period 1,	9 kgs. meadow hay,	644	14.8
Ox XX. Period 1,	10 kgs. meadow hay,	672	16.5
KELLNER'S EXPERIMENTS.			
Ox A,	8.5 kgs. meadow hay,	620	15.9
Ox B,	4.0 kgs. meadow hay, 5.0 kgs. oat straw,	612	15.9

The amounts of the several classes of nutrients digested and the nutritive effect of the feeding, as shown by the gain or loss of proteids and fat by the animal, computed per day and head in the customary way, were as follows:

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*Landw. Vers. Stat., 44, 257.

†Ibid. 47, 275.

‡Later results by Kellner (Landw. Vers. Stat., 50, 245,) upon the same subject were received after this article was in type and too late for insertion.

Rations and Nutritive Effect.

	Total dry matter. Grms.	Digestible.				Gain or loss of	
		N x 6.25. Grms.	Crude fiber. Grms.	Nitrogen-free extract. Grms.	Ether extract. Grms.	Proteids. Grms.	Fat. Grms.
KÜHN'S EXPERIMENTS.							
Ox II, Period 1,	8,384	412	1,765	2,610	79	+1	+89
Ox III, Period 1,	7,745	338	1,676	2,226	64	—16	+65
Ox IV, Period 1.a.,	7,627	339	1,662	2,259	65	—3	+112
Ox IV, Period 1.b.,	7,476	320	1,565	2,145	64	—36	—82
Ox V, Period 1,	7,784	451	1,572	2,315	40	+53	+124
Ox VI, Period 1,	7,703	458	1,642	2,420	47	+39	+153
Ox XX, Period 1,	8,482	540	1,560	2,999	132	+21	+88
KELLNER'S EXPERIMENTS.							
Ox A,	7,263	440	1,262	2,713	114	+39	+129
Ox B,	7,640	213	1,702	2,257	74	—91	—102

Kellner in his experiments determined the energy-content of the food, feces and urine of the animals, and likewise of the food and feces from four of Kühn's experiments. For the urine of the latter experiments he reckons 31.74 Cal. per gram of nitrogen, this being the result obtained in that one of his own experiments in which only hay was fed. For the remaining three experiments by Kühn, the writer has computed the available energy of the food from the digestible matter on the basis of 4.1 Cal. per gram of proteids, crude fiber and nitrogen-free extract, and 9.4 Cal.* per gram of ether extract. Adding the energy equivalent to any loss from the body to that of the food, and that equivalent to any gain by the body to that of the excreta, the difference represents the amount of energy evolved in the body. In the case of animals at rest, it may safely be assumed that this energy finally leaves the body in the form of heat, and that when, as in this case, the gains and losses are slight, it represents substantially the demands of the system for maintenance.

The balance of energy in the several experiments, as thus computed, was:

Energy per Day and Head.

	Ingesta. Cal.	Egesta. Cal.
KÜHN'S EXPERIMENTS.		
Ox II, Period 1.		
Food,	36,975.1	
Feces,		15,524.1
Urine (computed),		2,091.0
Methan,		3,114.1
Gain by body.		
1 grm. proteids,		5.7
89 grms. fat,		845.5
For maintenance,		15,394.7
	36,975.1	36,975.1

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*Kellner uses the factor 9.5 Cal. for fat.

Energy per Day and Head—Continued.

	Ingesta. Cal.	Egesta. Cal.
Ox III, Period 1.		
Available from food (computed),	17,985.6	
Loss from body.		
16 grms. proteids,	90.4	
Methan,		2,650.5
Gain by body.		
65 grms. fat,		617.5
For maintenance,		14,808.0
	18,076.0	18,076.0
Ox IV, Period 1.a.		
Available from food (computed),	18,077.0	
Loss from body.		
3 grms. proteids,	17.0	
Methan,		2,603.4
Gain by body.		
112 grms. fat,		1,064.0
For maintenance,		14,426.6
	18,094.0	18,094.0
Ox IV, Period 1.b		
Available from food (computed),	17,124.6	
Loss from body.		
36 grms. proteids.	203.5	
82 grms. fat,	779.0	
Methan,		2,477.0
For maintenance,		15,630.1
	18,107.1	18,107.1
Ox V, Period 1.		
Food,	34.211.5	
Feces.		15,312.2
Urine (computed),		2,018.7
Methan,		2,251.8
Gain by body.		
53 grms. proteids,		299.6
124 grms. fat,		1,178.0
For maintenance,		13,151.2
	34,211.5	34,211.5
Ox VI, Period 1.		
Food,	33,855.4	
Feces.		13,765.2
Urine (computed),		2,130.0
Methan,		2,462.4
Gain by body.		
39 grms. proteids,		220.5
153 grms. fat,		1,453.5
For maintenance,		13,823.8
	33,855.4	33,855.4
Ox XX, Period 1.		
Food,	37,167.3	
Feces,		13,880.7
Urine (computed),		2,641.7
Methan,		2,626.7
Gain by body.		
21 grms. proteids,		118.7
88 grms. fat,		836.0
For maintenance,		17,063.5
	37,167.3	37,167.3
KELLNER'S EXPERIMENTS:		
Ox A.		
Food,	32,177.3	
Feces,		11,750.3
Urine,		1,945.0
Methan,		2,098.2
Gain by body.		
39 grms. proteids,		220.5
139 grms. fat,		1,320.5
For maintenanee,		14,842.8
	32,177.3	32.177.3
Ox B.		
Food,	33,794.4	
Loss from body.		
91 grms, proteids,	*514.4	
102 grms. fat,	969.0	
Feces,		14,576.1
Urine,		1,549.4
Methan,		2,314.1
For maintenance,		16,838.2
	35,277.8	35,277.8

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*As given in the original, 405.3 Cal. Kellner obtained this result by deducting from the tota energy of the 91 grms. of proteids the energy of the resulting urine as computed from Rubner's results. All the products of the metabolism of this 91 grms. of proteids, however, must have found their way into the excreta, and their potential energy appears under the head of egesta Consequently, the proteids lost from the body should be reckoned at their full calorific value, a: is done above. The difference is immaterial, however, so far as concerns the main results of th experiment.

In order to render the above results comparable, it is desirable to reduce them to a uniform live-weight—conveniently to 500 kgs., as in the previous experiments. This has usually been done by assuming the maintenance ration to be proportional to the weight of the animal, and the custom has been followed in the case of the experiments previously cited, in view of the approximate nature of the results, although its propriety is more than questionable.

The function of the maintenance ration is essentially to supply heat to the body to replace the constant loss that takes place. Now, Henneberg* has long ago shown that, in round numbers, over 90 per cent. of this heat is removed by radiation and evaporation. Consequently, we should expect the demands of the organism for heat (i. e., for maintenance), to be proportional to its surface (including lung surface), rather than to its weight, and the more recent researches of Rubner† have confirmed this theoretical conclusion. While we have no measurements of the surfaces of the animals experimented on, we may, for the purpose of this calculation, assume without material error that they were geometrically "similar figures," and therefore that their surfaces were proportional to the two-thirds powers of their weights. This method of computation has been used in computing the energy per 500 kgs. in the following summary, but the nitrogenous matter has been computed in the usual way:

Summary of Maintenance Rations.

	Live weight.	Per Day and Head.		Per 500 kgs. Live Weight.	
		N x 6.25. Grms.	Energy. Cal.	N x 6.25. Grms.	Energy. Cal.
KUHN'S EXPERIMENTS.					
1. Ox II, Period 1, ...	632	413	15,395	327	13,168
2. Ox III, Period 1, ...	632	338	(14,808)	267	(12,666)
3. Ox IV, Period 1.a., ...	631	339	(14,427)	269	(12,350)
4. Ox IV, Period 1.b., ...	623	320	(15,630)	257	(13,497)
5. Ox V, Period 1, ...	602	451	13,151	375	11,616
6. Ox VI, Period 1, ...	644	458	13,824	356	11,679
7. Ox XX, Period 1, ...	672	540	17,064	402	14,009
KELLNER'S EXPERIMENTS.					
8. Ox A, ...	620	440	14,843	355	12,862
9. Ox B, ...	612	213	16,838	174	14,717
Average of all, ...	629.8	390	15,109	309	12,952
Average, excluding Nos. 2, 3 & 4,	630.3	419	15,186	334	13,008
Average of Nos. 8 & 9, ...	616.0	327	15,341	265	13,790

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*Neue Beiträge, etc., 1871, p. 227.

†Zeit. f. Biol., 19, 535.

Kellner,* by a slightly different manner of averaging, obtained as the maintenance ration of a steer weighing 630.3 kgs. (average of Nos. 1, 5, 6, 7, 8 and 9 of the table) 15,167.5 Cal., and from this computes the maintenance ration for 1,000 kgs. live weight to be 24,064 Cal., or, in round numbers, 1 Cal. per kilogram per hour, on the assumption that the maintenance ration is proportional to the live-weight. The calculation in proportion to the two-thirds power of the weight of course gives a higher result, and one which, in view of Rubner's results, as cited by Kellner himself, we must regard as corresponding more nearly to the truth.

EXPERIMENTS AT THIS STATION.

The Station does not possess a respiration apparatus, and hence had not the means for scientifically accurate determinations of the gain or loss of fat by the animals under experiment. It was believed, however, that by so adjusting the rations as to produce as nearly as possible a constant live-weight during *long periods*, and at the same time determining the gain or loss of nitrogen by the animals, results might be reached which would be substantially accurate. How far this assumption was justified, the reader must judge from the results of the experiments.

EXPERIMENTS OF 1892-3.

ANIMALS.

The animals used for the experiments were three steers, apparently grade short horns, purchased in Pittsburgh, and evidently past two years old. The same three animals were used for all the subsequent experiments of this series. They were fed nothing but hay previous to the beginning of the experiment.

GENERAL PLAN.

The general plan of the experiments was to feed clear timothy hay (*Phleum pratense*) in sufficient amount to maintain the animals, as nearly as could be judged from their daily live-weights and general appearance, and when equilibrium was established between the food and live weight, to determine the digestibility of the ration and the proteid metabolism in a special digestion period of seven days. The results of later experiments appear to indicate that a seven-day digestion period is rather short for this purpose, but the results are given here for what they are worth. The temperature of the stable probably did not vary greatly from 40 to 50 degrees F.

METHODS.

The hay, which was nearly pure timothy, was cut up, mixed and stored in advance, and was weighed out daily for the animals, no samples being taken. For the digestion periods it was weighed out for seven days in advance in bags and sampled by taking a handful from each bag as it was filled.

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*Loc. cit., p. 313.

During the digestion periods, the feces were collected by a watchman, on shovels, weighed daily, carefully mixed, and 1-100 of the total amount taken for air-drying. The air-drying in this and in subsequent experiments was executed in a steam-drying closet, at a temperature of about 60 degrees C. Experiments by Frear & Holter* at this Station have shown that no material loss of nitrogen takes place from the feces of steers fed exclusively on hay when dried in this way.

The air-dry samples from each animal for the whole period were combined and analyzed. The urine was collected in the rubber bags used in previous digestion experiments,† which were emptied at intervals during the day and rinsed out with distilled water at the close of the twenty-four hours. The urine and wash water were thoroughly mixed and a daily determination of nitrogen made by the Kjeldahl method. The analytical methods were those of the Association of Official Agricultural Chemists. Proteids and non-proteids were determined by precipitation of the former with copper hydrate. The determinations of energy in food and excreta were made by means of the Berthelot bomb calorimeter, as modified by Hempel and Atwater.

Experiment I.

Dec. 1, 1892 to Jan. 21, 1893—52 days.

The daily ration consisted of 4.563 kgs. (10 lbs.) of timothy hay, containing a very slight admixture of clover. From the results of the earlier weighings, it was thought that this amount would suffice to maintain the animals and arrangements were accordingly made for the digestion period. This period covered the time from Jan. 15 to 21 inclusive. The following data show the amounts of excretion during that time:

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*Report, 1891, p. 123; Agr. Science, 6, 268.

†Report, 1885-6, p. 182; Agr. Science, 2, 149.

	Feces.		Urine.		
	Fresh-weight. Grms.	Air-dry weight. Grms.	Weight. Grms.	Nitrogen. Per cent.	Weight of nitrogen. Grms.
STEER 1:					
January 15th,	8,860	1,991	2,224	0.97	21.57
January 16th,	8,644	2,010	2,306	0.87	20.07
January 17th,	7,804	1,801	2,497	0,92	22.97
January 18th,	8,676	1,895	1,776	0.98	17.41
January 19th,	7,632	1,607	4,440	0.65	28.86
January 20th,	8,000	1,499	3,064	0.70	21.45
January 21st,	7,882	1,606	4,276	0.61	26.08
Average,	8,207	1,773	2,940	....	22.63
STEER 2:					
January 15th,	8,728	2,007	2,672	0.69	18.44
January 16th,	8,700	1,799	2,664	0.76	20.25
January 17th,	7,944	2,011	2,294	0.77	17.66
January 18th,	8,700	1,900	2,672	0.74	19.77
January 19th,	8,556	1,890	4,204	0.53	22.28
January 20th,	8,200	1,500	2,168	0.66	14.32
January 21st,	7,615	2,004	3,910	0.62	24.24
Average,	8,349	1,873	2,940	....	19.57
STEER 3:					
January 15th,	12,400	2,699	2,308	0.74	17.08
January 16th,	11,672	2,295	3,000	0.76	22.80
January 17th,	10,944	2,108	2,560	0.68	17.41
January 18th,	10,480	1,697	4,692	0.48	22.52
January 19th,	12,010	1,701	5,140	0.51	26.21
January 20th,	12,888	1,798	5,700	0.33	18.81
January 21st,	10,140	1,500	4,664	0.45	20.99
Average,	11,505	1,972	4,001	....	20.83

The amounts of fresh feces and urine excreted by Nos. 1 and 2 do not differ greatly, but nearly or quite 50 per cent. more of each was excreted by No. 3 than by the other two animals. In the case of the feces, the larger part of this difference consisted of water, the percentages of dry matter in the fresh feces being:

Steer 1,	20.66 per cent.
Steer 2,	21.55 per cent.
Steer 3,	16.46 per cent.

The percentage of dry matter in the urine was not determined, but the amounts of nitrogen found do not differ greatly and indicate that in this case, too, the excess excreted by Steer No. 3 consisted largely of water.

The composition of the hay and of the air-dry feces was as follows:

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Percentage Composition.

	Hay.	Feces.		
		Steer 1.	Steer 2.	Steer 3.
Loss in air-drying,	3.40			
Composition, air-dry.				
Water,	3.66	4.38	4.01	4.03
Ash,	5.31	7.42	7.38	6.60
Proteids,	5.84	7.63	7.53	6.97
Non-proteids,	.44			
Crude fiber,	34.20	39.17	39.38	38.70
Nitrogen-free extract,	48.38	38.93	39.31	41.49
Ether extract,	2.17	2.47	2.39	2.21
	100.00	100.00	100.00	100.00
Total nitrogen,	1.005	1.220	1.205	1.115
Composition of dry matter.				
Ash,	5.51	7.76	7.69	6.88
Proteids,	6.06	7.98	7.84	7.26
Non-proteids,	0.46			
Crude fiber,	35.50	40.96	41.02	40.33
Nitrogen-free extract,	50.22	40.72	40.96	43.23
Ether extract,	2.26	2.58	2.49	2.30
	100.00	100.00	100.00	100.00
Total nitrogen,	1.043	1.276	1.255	1.162
	Cal.	Cal.	Cal.	Cal.
Energy per gram of dry matter,	4.430	4.631	4.609	4.617

The above data give the following figures for the digestibility of the hay:

Per Day and Head

	Fresh substance. Grams.	Dry matter. Grams.	Ash. Grams.	Organic matter. Grams.	Total N x 6.25. Grams.	Proteids. Grams.	Non-proteids.* Grams.	Crude fiber. Grams.	Nitrogen-free extract. Grams.	Ether extract. Grams.	Energy. Cal.
STEER 1:											
Hay eaten,	4,536	4,003	221	3,782	261	243	18	1,421	2,010	90	17,373
Feces,	8,207	1,695	132	1,563	135	135	....	694	690	44	7,850
Digested,	....	2,308	89	2,219	126	108	18	727	1,320	46	9,523
Per cent. digested,	....	57.66	40.27	58.68	48.28	44.45	100	51.16	65.68	51.12	54.81
STEER 2:											
Hay eaten,	4,536	4,003	221	3,782	261	243	18	1,421	2,010	90	17,373
Feces,	8,349	1,798	138	1,660	141	141	....	738	736	45	8,287
Digested,	....	2,205	83	2,122	120	102	18	683	1,274	45	9,086
Per cent. digested,	....	55.08	37.55	56.10	45.98	41.98	100	51.94	63.38	50.00	52.30
STEER 3:											
Hay eaten,	4,536	4,003	221	3,782	261	243	18	1,421	2,010	90	17,373
Feces,	11,506	1,893	130	1,763	137	137	....	763	819	44	8,740
Digested,	....	2,110	91	2,019	124	106	18	658	1,191	46	8,633
Per cent. digested,	....	52.71	41.18	53.38	47.51	43.63	100	46.31	59.25	61.12	49.69
SUMMARY OF COEFFICIENTS:											
Steer 1,	....	57.66	40.27	58.68	48.28	44.45	100	51.16	65.68	51.12	54.81
Steer 2,	....	55.08	37.55	56.10	49.58	41.98	100	51.94	63.38	50.00	52.30
Steer 3,	....	52.71	41.18	53.38	47.51	43.63	100	46.31	59.25	51.12	49.69

*Assumed to be wholly digestible.

It will be noticed that the results for the three animals do not agree very closely. As already pointed out, the feces of No. 3 contained much more water than those of Nos. 1 and 2, although the percentage is not excessive. Taken in connection with the larger total excretion, however, they perhaps indicate an abnormal peristaltic action of the intestines, and tend to throw doubt upon the correctness of the co-efficients of digestibility obtained. It should perhaps be added, however, that in several of the later experiments, although not in all, No. 3 gave co-efficients lower than those of No. 1 by from 1.0 to 2.6 per cent. No obvious explanation exists of the differences between Nos. 1 and 2. Indeed, in nearly all of these experiments, No. 2 showed a distinctly greater digestive capacity than No. 1.

PROTEID METABOLISM.

For the proteid metabolism, the data above recorded give the following figures, showing that the ration was insufficient to maintain the animals in nitrogen equilibrium.

	Steer 1.		Steer 2.		Steer 3.	
	Grms.	Grms.	Grms.	Grms.	Grms.	Grms.
Nitrogen in food,		41.75		41.75		41.75
Nitrogen in feces,	21.63		22.57		22.00	
Nitrogen in urine,	22.63		19.57		20.83	
Nitrogen in total excretion,		44.26		42.14		42.83
Nitrogen lost from body,		2.51		0.39		1.08
Equivalent proteids,		15.69		2.44		6.75

LIVE WEIGHTS.

The animals were weighed daily at 1 P. M. There were considerable variations in the weights from day to day, as is usually the case, undoubtedly due largely to variations in the amounts of water consumed. In order to eliminate to a certain extent these accidental variations, the live weights have been averaged in overlapping ten-day periods, the average of the first ten days being entered opposite the fifth day of the experiment, the average of the second to the 11th days, inclusive, opposite the sixth day, the average for the third to the 12th days, inclusive, opposite the seventh day, and so on. The temperature of the stable was recorded continuously by means of a Draper metallic thermometer, but, by an unfortunate neglect, the records after December were not dated, and are therefore worthless. The average temperature for each day was estimated as closely as possible by inspection of the thermometer tracings. It is believed that no material error is involved in this method, and that an effort after extreme accuracy by the use of the planimeter would have been superfluous. The following tables contain the daily weighings, the temperature of the stable, and the ten-day averages computed as above explained:

Daily Weights and Temperature of Stable.

Day ending 1 P. M.	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.	Temperature of stable. °F.
December 1, 1892,	442.9	456.5	407.3	52
December 2, 1892,	429.3	445.4	411.2	51
December 3, 1892,	429.6	451.8	407.3	51
December 4, 1892,	432.5	460.4	414.8	53
December 5, 1892,	430.2	452.9	406.7	53
December 6, 1892,	433.2	464.5	401.9	51
December 7, 1892,	420.7	458.6	409.1	53
December 8, 1892,	428.6	464.9	402.8	57
December 9, 1892,	422.7	458.2	408.2	57
December 10, 1892,	430.5	450.6	401.4	62
December 11, 1892,	425.5	458.2	396.9	52
December 12, 1892,	437.5	449.1	403.7	50
December 13, 1892,	428.4	461.8	396.2	51
December 14, 1892,	422.3	449.5	409.1	50
December 15, 1892,	429.1	463.1	400.1	53
December 16, 1892,	418.7	415.0	404.8	53
December 17, 1892,	437.3	462.7	416.0	54
December 18, 1892,	430.9	463.6	409.1	53
December 19, 1892,	420.9	461.1	413.0	53
December 20, 1892,	430.2	457.2	405.7	53
December 21, 1892,	421.8	455.4	415.0	49
December 22, 1892,	431.1	455.6	403.7	46
December 23, 1892,	428.7	446.0	397.3	46
December 24, 1892,	425.2	462.2	412.8	44
December 25, 1892,	417.1	449.1	403.2	44
December 26, 1892,	418.2	453.6	401.9	44
December 27, 1892,	422.3	444.5	415.0	42
December 28, 1892,	426.4	455.9	403.7	44
December 29, 1892,	432.7	449.5	410.5	46
December 30, 1892,	418.9	460.5	414.8	....
December 31, 1892,	420.5	447.9	404.6	....
January 1, 1893,	425.0	457.2	413.0	....
January 2, 1893,	417.3	449.1	399.2	....
January 3, 1893,	430.9	455.0	409.4	....
January 4, 1893,	423.4	444.1	399.2	....
January 5, 1893,	418.0	452.2	409.6	....
January 6, 1893,	419.6	441.8	399.2	....
January 7, 1893,	423.2	453.6	413.2	....
January 8, 1893,	420.7	440.0	403.0	....
January 9, 1893,	415.7	452.9	415.5	....
January 10, 1893,	417.3	438.8	406.0	....
January 11, 1893,	411.4	442.5	411.4	....
January 12, 1893,	428.6	443.4	399.6	....
January 13, 1893,	415.2	443.6	395.5	....
January 14, 1893,	408.2	442.2	413.7	....
January 15, 1893,	425.9	445.0	403.0	....
January 16, 1893,	413.7	434.7	400.7	....
January 17, 1893,	423.7	444.5	398.7	....
January 18, 1893,	412.3	431.6	381.9	....
January 19, 1893,	408.2	444.7	399.2	....
January 20, 1893,	408.3	430.0	381.0	....
January 21, 1893,	415.7	444.7	397.8	....

Ten-day Averages of Live Weights.

Date.	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.
December 1-10,	430.0	455.9	407.1
December 2-11,	428.3	456.1	406.0
December 3-12,	429.1	456.4	405.3
December 4-13,	429.0	457.4	404.2
December 5-14,	428.0	456.3	403.6
December 6-15,	427.9	457.4	402.9
December 7-16,	426.4	455.9	403.2
December 8-17,	428.1	456.8	403.9
December 9-18,	428.3	457.2	404.6
December 10-19,	428.1	457.5	405.0
December 11-20,	428.1	458.1	405.5
December 12-21,	427.7	457.9	407.3
December 13-22,	427.1	458.5	407.3
December 14-23,	427.1	456.8	407.4
December 15-24,	427.4	458.1	407.8
December 16-25,	426.2	456.7	408.1
December 17-26,	426.1	457.1	407.8
December 18-27,	424.6	455.2	407.7
December 19-28,	424.2	454.0	407.1
December 20-29,	425.4	452.8	406.9

Ten-day Averages of Live Weights—**Continued.**

Date.	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.
December 21-30,	424.2	453.1	407.8
December 22-31,	424.1	452.4	406.8
December 23-January 1,	423.5	452.5	407.7
December 24-January 2,	422.4	453.0	407.9
December 25-January 3,	422.9	452.2	407.5
December 26-January 4,	423.6	451.7	407.1
December 27-January 5,	423.5	451.6	407.9
December 28-January 6,	423.3	451.3	406.3
December 29-January 7,	423.0	451.1	407.3
December 30-January 8,	421.8	450.1	406.5
December 31-January 9,	421.4	449.4	406.6
January 1-10,	421.1	448.5	406.7
January 2-11,	419.8	447.0	406.6
January 3-12,	420.9	446.4	406.6
January 4-13,	419.3	445.3	405.2
January 5-14,	417.8	445.1	406.7
January 6-15,	418.6	444.4	406.0
January 7-16,	418.0	443.7	406.2
January 8-17,	418.0	442.8	404.7
January 9-18,	417.2	441.9	402.6
January 10-19,	416.5	441.1	401.0
January 11-20,	415.5	440.2	398.5
January 12-21,	416.0	440.4	397.1
January 13-22,	413.8	439.4	395.5
January 14-23,	413.9	439.9	395.1
January 15-24,	413.8	439.2	391.9
January 16-25,	413.1	439.3	391.7
January 17-26,	412.7	440.7	389.9
January 18-27,	411.0	440.2	391.3
January 19-28,	410.8	441.6	392.1
January 20-29,	412.3	440.9	393.0
January 21-30,	412.5	443.0	394.3

These weights are represented graphically in the left hand portion of Plate I, the lighter black line representing the daily weights and the heavier red line the ten-day averages.

The rations were plainly insufficient to maintain the animals, the individual weighings and especially the ten-day averages showing a steady and fairly constant loss by No. 1 and likewise by No. 2 after the first 17 days. In the case of No. 3, the live weight was apparently well maintained for about 40 days, but then follows a very rapid falling off, beginning a few days before the digestion trial. It will be recalled that the results of the latter showed a large excretion of water by No. 3 as compared with Nos. 1 and 2. This fact, together with the sudden drop in the weight, strongly suggests that the animal had really been losing tissue throughout the experiment and storing up water in its place, and that the latter was rapidly abstracted during the last ten days of the period. A similar sudden loss of weight after a comparatively long period of apparent maintenance was observed with all three of the animals in a later experiment (p. 72 and Plates V, VI and VII), although in that case no data were obtained as to the excertion of water. It seems probable, therefore, that we are justified in regarding the apparent maintenance of No. 3 as fictitious, and in taking the average weight at the close of the period as the basis for a comparison with the initial weight.

The plate shows, however, more or less fluctuation of the average weight of Nos. 2 and 3 during the first two weeks of the period, and it seems safer to omit this time from the comparison. Taking, then, the averages of December 12-21 and Jan. 12-21, we have the following results for the loss of live weight.

Loss of Live Weight.

	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.
Weight, December 12-21,	427.7	457.9	407.3
Weight, January 12-21,	416.0	440.4	397.1
Loss,	11.7	17.5	10.2
Loss per day,	0.377	0.564	0.329

Connecting the points on the plate corresponding to the above averages by the black broken line, and producing the latter through the rest of the period, we see that with Nos. 1 and 2 it corresponds quite closely with the general course of the live weight. In the case of No. 3 the interpretation is more difficult, for the reasons already pointed out. The diagram would perhaps indicate that the comparison should be made between an earlier and a later date, e. g., between the averages for Dec. 9-18 and Jan. 16-25. This, however, would make no material difference in the computed loss per day. On the whole, it seems safer to make the comparison for all three animals between the same dates, accepting the results for No. 3 with some reserve.

In the lack of a respiration apparatus, we have no exact data as to the composition of this loss and the amount of energy contributed by it to the maintenance of the animals, but it is perhaps possible to make an approximation to it which is of some value. Assuming that the average loss per day, as just computed, represents substantially a loss of tissue and not, to any material extent, a change in the amount of "ballast" in the alimentary canal, this loss is made up in the main of ash, proteids, fat and water. The loss of proteids was determined. That of ash was not, but, owing to its small amount, it may be safely neglected in these approximate computations. There remain to be considered water and fat. Of these, the water appears to be associated in the body with the proteids, while the fat is simply deposited as such in the cells of the fat tissues.

Rubner* gives the following data for the composition of the fat-free flesh:

Dry matter,	23.07 per cent.
Nitrogen in dry matter,	15.40 per cent.
Nitrogen in fresh substance,	3.55 per cent.

Lawes & Gilbert's† determinations of the composition of the increase of live weight in fattening show substantially the same composition for the nitrogenous tissue gained. For oxen their results were:

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*Zeit. f. Biol. 21, 310-311.

†Jour. Roy. Agr. Soc., 21, 433.

Water,	24.64 per cent.
Proteids,	7.69 per cent.
Fat,	66.20 per cent.
Ash,	1.47 per cent.
	100.00 per cent.

Considering the water, proteids and ash to represent the nitrogenous tissue (flesh) gained, we find the percentage composition of the latter to have been:

Water,	72.90 per cent.
Proteids,	22.75 per cent.
Ash,	4.35 per cent.
	100.00 per cent.

equivalent to:

Dry matter,	27.10 per cent.
Nitrogen in fresh substance,	3.64 per cent.

Considering the nature of the experiments, these results agree as closely as could be expected with Rubner's figures, especially when we consider that a part of the gain of ash was probably due to the growth of the skeleton.

In the computation of this and the succeeding experiments, Rubner's figure for nitrogen (3.55 per cent.) has been employed; that is, a gain or loss of one gram of nitrogen is considered to represent a gain or loss of 28.17 grams of "flesh." Furthermore, it has been assumed that the "flesh" thus computed includes all the gain or loss of water, and that the algebraic difference between this amount and the total gain or loss of weight represents the gain or loss of fat. The method is of course but an approximation, but fortunately in most of our experiments the amounts involved are not large.

Applied to this experiment the method yields the following results per day and head:

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Loss of nitrogen,	2.51	0.39	1.08
Equivalent to flesh,	70.7	11.0	30.4
Total loss of weight,	377.0	564.0	329.0
Computed loss of fat,	306.3	553.0	298.6

On the basis of these figures we can compute the total production of heat by the animals in the same manner as in Kühn's experiments. In these computations the energy of one gram of proteids has been reckoned at 5.724 Cal., this being the average of determinations by Berthelot and by Stohmann and Langbein of the heat of combustion with muscle with extractives and fat removed. For the energy of the fat, Stohmann and Langbein's figures for beef fat, viz., 9.486 Cal. per gram, have been used.* The energy of the urine has been computed from its nitrogen, one gram of the latter being reckoned equivalent to 16.6 Cal., this being the average of direct determinations in later experiments upon these same three animals upon similar feed.

No means were available in these experiments for determining the excretion of methan, but an approximate estimate of it may be made. G. Kühn* has shown that both the crude fiber and nitrogen-free extract of the food take part in the production of this gas, although probably not to the same degree, while the proteids and fat of the food probably do not. On the average of 20 experiments upon 5 different animals, with rations not widely different from those used in this and subsequent experiments, 7.66 per cent. of the carbon of the crude fiber plus nitrogen-free extract was excreted as hydrocarbons, presumably methan, the extremes being 6.9 per cent. and 8.5 per cent. The average is equivalent to 4.55 grams of methan from each 100 grams of these ingredients digested, assuming the digested portion to have the composition of starch. We shall perhaps not go very far astray in applying this average to our experiments and thus securing an approximate estimate of the amount of unused energy of the food thus carried off.

For this experiment, the results of this computation are:

Estimated Production of Methan.

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Crude fiber digested,	727	683	658
Nitrogen-free extract, digested,	1,320	1,274	1,191
Total,	2,047	1,957	1,849
Methan (computed),	93	89	84
Equivalent energy.	Cal.	Cal.	Cal.
(1 grm. CH_4 equal 13.246 Cal.),	1,232	1,179	1,113

The income and outgo of energy per day and head, on the basis of these assumptions, was as follows:

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*Compare Atwater; U. S. Dept. Agr., Office of Expt. Stations, Bul. 21, p. 127.

†Loc. cit., p. 561.

Energy per Day and Head.

	Steer 1.		Steer 2.		Steer 3.	
	Ingesta. Cal.	Egesta. Cal.	Ingesta. Cal.	Egesta. Cal.	Ingesta. Cal.	Egesta. Cal.
Food,	17,373		17,373		17,373	
Loss from body:						
Proteids,	90		14		39	
Fat (estimated),	2,905		5,246		2,832	
Excreta:						
Feces,		7,850		8,287		8,740
Urine (estimated),		376		325		346
Methan (estimated,		1,232		1,179		1,113
For maintenance,		10,910		12,842		10,045
	20,368	20,368	22,633	22,633	20,244	20,244

Calculating the results of this period to the uniform live weight of 500 kgs. on the assumption that the maintenance ration is proportional to the two-thirds power of the live weight, we have the following:

Maintenance Ration per Day.

	Average live weight. Kgs.	Energy.	
		Per head. Cal.	Per 500 kgs. live weight. Cal.
Steer 1,	420	10,910	12,260
Steer 2,	450	12,842	13,780
Steer 3,	400	10,045	11,650

There is a considerable discrepancy between the result for No. 2 and those for Nos. 1 and 3, but it must be borne in mind that these results include a large and uncertain portion computed from the loss in live weight.

The loss of weight is not, in itself, a disadvantage. Rubner* has shown that with the dog the amount of proteids and fat metabolized in the body during hunger is a measure of the maintenance requirements of the organism. For obvious reasons, this method cannot be applied to the herbivora. It appears altogether probable, however, that when the latter are put upon an insufficient ration, the loss from the body will be limited, as in the case of the fasting dog, to the amount required to make up the maintenance ration. If this be true, experiments with the respiration apparatus, or especially with a respiration-calorimeter, under these conditions, should yield the most accurate determinations of the total demands of the organism for potential energy.

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*Zeit. f. Biol., 19, 313.

In the present experiment the uncertainty arises, not from the fact of a loss of weight, but from the lack of means for accurately determining the amounts of proteids and fat which it represents.

Experiment II.

Jan. 22 to April 2d, 1893.—71 Days.

The ration of the previous period having proved insufficient, it was increased to 5.44 kilograms (12 lbs.) of the same timothy hay. As will be seen from the analysis given below, the hay used in this period contained slightly more ash and nitrogen, and therefore less nitrogen-free extract, than the sample of the previous period. Presumably these differences were due to a slightly greater admixture of clover, but they are not sufficiently serious to disturb the experiment.

DIGESTIBILITY.

The excretion during the special digestion period, Feb. 19-25, inclusive, was as follows:

	Feces.		Urine.		
	Fresh weight. Grms.	Air-dry weight. Grms.	Weight. Grms.	Nitrogen. Per cent.	Weight of nitrogen. Grms.
STEER 1:					
February 19,	9.147	1,808	4,196	0.59	24.76
February 20,	12,112	2,502	3,868	0.66	25.53
February 21,	13,217	2,604	4,804	0.66	31.71
February 22,	11,763	2,392	5,336	0.58	30.95
February 23,	10,412	2,308	3,812	0.69	26.30
February 24,	13,672	2,794	4,602	0.83	38.20
February 25,	13,916	2,803	2,804	0.77	21.59
Total,	84,238	17,206	29,422	....	199.04
STEER 2:					
February 19,	8,021	1,404	4,574	0.52	23.78
February 20,	12,462	2,493	4,182	0.55	23.00
February 21,	9,496	1,799	4,776	0.61	29.13
February 22,	11,552	2,190	5,532	0.58	32.09
February 23,	9,624	2,106	4,916	0.61	29.99
February 24,	9,622	2,205	6,560	0.55	36.08
February 25,	10,776	2,394	6,560	0.48	31.49
Total,	71,552	14,591	37,100	....	305.56
STEER 3:					
February 19,	13,881	2,996	5,429	0.46	24.97
February 20,	12,000	2,200	2,881	0.54	15.56
February 21,	11,685	2,397	4,776	0.62	29.61
February 22,	12,140	2,207	6,958	0.48	33.40
February 23,	11,744	2,509	3,588	0.73	26.19
February 24,	13,420	2,405	5,996	0.62	37.18
February 25,	13,756	2,591	3,420	0.57	19.49
Total,	88,626	17,305	33,048	....	186.40

The composition of food and excreta and the percentage digestibility of the former were as follows:

Percentage Composition.

	Hay.	Feces.		
		Steer 1.	Steer 2.	Steer 3.
Loss in air-drying,	9.00	....	....	....
Composition, air-dry:				
Water,	4.59	5.01	4.77	4.98
Ash,	5.95	6.49	7.25	6.51
Proteids,	7.13	7.81	8.19	7.50
Non-proteids,	0.56			
Crude fiber,	33.92	39.62	39.29	37.50
Nitrogen-free extract,	45.83	38.81	38.24	41.33
Ether extract,	2.02	2.26	2.26	2.18
	100.00	100.00	100.00	100.00
Total nitrogen,	1.230	1.250	1.310	1.200
Composition of dry matter:				
Ash,	6.24	6.83	7.61	6.85
Proteids,	7.47	8.22	8.60	7.90
Non-proteids,	0.59			
Crude fiber,	31.55	41.71	41.26	39.47
Nitrogen-free extract,	48.03	40.86	40.16	43.49
Ether extract,	2.12	2.38	2.37	2.29
	100.00	100.00	100.00	100.00
Total nitrogen,	1.289	1.316	1.376	1.263
	Cal.	Cal.	Cal.	Cal.
Energy per gram of dry matter,	4.422	4.725	4.707	4.721

Per Day and Head.

	Fresh substance. Grams.	Dry matter. Grams.	Ash. Grams.	Organic matter. Grams.	Total N x 6.25. Grams.	Proteids. Grams.	Non-proteids.* Grams.	Crude fiber. Grams.	Nitrogen-free extract. Grams.	Ether extract. Grams.	Energy. Cal.
STEER 1:											
Hay eaten,	5,444	4,726	295	4,431	381	353	28	1,680	2,270	100	20,898
Feces,	12,084	2,335	159	2,176	192	192	....	974	954	56	11,033
Digested,	....	2,391	136	2,255	189	161	28	706	1,316	44	9,865
Per cent. digested,	....	50.59	46.10	50.89	49.61	45.61	100	42.02	57.97	44.00	47.20
STEER 2:											
Hay eaten,	5,444	4,726	295	4,431	381	353	28	1,680	2,270	100	20,898
Feces,	10,222	1,985	151	1,834	171	171	....	819	797	47	9,343
Digested,	....	2,741	144	2,597	210	182	28	861	1,473	53	11,555
Per cent. digested,	....	58.00	48.81	58.61	55.12	51.56	100	51.25	64.90	53.00	55.30
STEER 3:											
Hay eaten,	5,444	4,726	295	4,431	381	353	28	1,680	2,270	100	20,898
Feces,	12,661	2,349	161	2,188	186	186	....	927	1,021	54	11,090
Digested,	....	2,377	134	2,243	195	167	28	753	1,249	46	9,808
Per cent. digested,	....	50.30	45.43	50.62	51.18	47.31	100	44.82	55.02	46.00	46.93
SUMMARY OF COEFFICIENTS:											
Steer 1,	....	50.59	46.10	50.89	49.61	45.61	100	42.02	57.97	44.00	47.20
Steer 2,	....	58.00	48.81	58.61	55.12	51.56	100	51.25	64.90	53.00	55.30
Steer 3,	....	50.30	45.43	50.62	51.18	47.31	100	44.82	55.02	46.00	46.93

*Assumed to be completely digestible.

As compared with the results of the first period, Steers 1 and 3 show a less digestibility of dry matter, organic matter and total energy, while in the case of No. 2 the result is the reverse. In all cases, the total nitrogen and the proteids were more completely digested than in the first period, possibly owing to the higher percentage of this ingredient contained in the hay. The results on Nos. 1 and 3 agree very closely while those with No. 2 are higher. As already stated, this was the case in most of these experiments, but the difference in this case is notably greater than in any other trial. Nothing appears in the records of this experiment, however, to suggest any abnormal conditions. The excretion from day to day was fairly regular, the percentage of dry matter in the feces of the three animals was nearly the same (19.41 for No. 1; 19.42 for No. 2 and 18.56 for No. 3) and the live weights fail to indicate any abnormally large or small excretion.

PROTEID METABOLISM.

For the proteid metabolism, we have the following figures per day and head:

	Steer 1.		Steer 2.		Steer 3.	
Nitrogen in food,		60.92		60.92		60.92
Nitrogen in feces,	30.78		27.32		29.67	
Nitrogen in urine,	28.43		29.37		26.63	
Nitrogen in total excretion,		59.16		56.69		56.30
Gain of nitrogen,		1.76		4.23		4.62
Equivalent proteids,		11.00		26.44		28.88

The ration produced a slight gain of proteids in the case of No. 1 and a somewhat greater gain in the case of Nos. 2 and 3.

LIVE WEIGHTS.

The animals were weighed daily as in the previous experiment, with the following results:

Day ending 1 P. M.	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.
January 22,	406.4	432.7	383.3
January 23,	416.8	443.6	391.9
January 24,	406.9	435.9	381.5
January 25,	418.7	445.9	400.5
January 26,	410.5	448.2	383.3
January 27,	406.0	439.5	412.8
January 28,	411.0	445.9	390.1
January 29,	422.7	437.3	408.2
January 30,	410.5	451.3	393.3
January 31,	415.0	439.5	408.2
February 1,	411.0	449.1	399.1
February 2,	424.6	449.1	407.3
February 3,	414.8	450.0	390.5
February 4,	420.0	445.4	408.2
February 5,	421.8	455.9	393.7
February 6,	415.9	437.7	377.4
February 7,	430.0	451.8	408.2
February 8,	415.9	443.6	394.6

Live Weights—Continued.

Day ending 1 P. M.	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.
February 9,	425.0	453.6	404.6
February 10,	419.6	453.6	389.2
February 11,	422.3	446.8	403.2
February 12,	420.0	448.2	392.4
February 13,	417.8	446.8	410.5
February 14,	424.1	449.1	396.2
February 15,	410.5	442.2	403.7
February 16,	428.6	449.5	398.7
February 17,	413.7	447.0	412.1
February 18,	428.6	448.2	396.1
February 19,	413.7	440.9	407.8
February 20,	427.3	444.5	396.5
February 21,	426.8	440.4	407.3
February 22,	421.4	447.2	390.5
February 23,	412.8	444.5	406.9
February 24,	429.1	445.0	387.8
February 25,	411.4	446.8	402.8
February 26,	419.6	443.6	391.0
February 27,	408.2	447.7	398.7
February 28,	420.9	445.4	391.4
March 1,	409.6	441.3	395.5
March 2,	420.9	445.9	396.4
March 3,	409.1	446.8	394.2
March 4,	430.0	448.3	401.9
March 5,	414.6	446.8	385.6
March 6,	414.1	446.3	396.9
March 7,	417.7	444.1	405.1
March 8,	420.7	439.1	390.5
March 9,	420.5	440.0	402.3
March 10,	419.6	438.2	383.3
March 11,	419.1	438.6	407.3
March 12,	415.2	440.4	390.1
March 13,	418.2	441.8	400.5
March 14,	409.6	445.4	385.6
March 15,	424.6	445.4	412.8
March 16,	405.1	440.0	391.0
March 17,	413.7	443.2	400.5
March 18,	409.8	445.4	392.3
March 19,	407.3	442.2	397.3
March 20,	408.2	446.3	383.7
March 21,	410.5	445.0	406.0
March 22,	403.7	448.2	383.3
March 23,	411.4	440.9	403.2
March 24,	400.5	447.7	385.1
March 25,	417.7	442.0	408.7
March 26,	401.2	447.5	381.9
March 27,	420.0	450.4	408.2
March 28,	406.4	450.4	399.2
March 29,	421.8	450.4	407.1
March 30,	413.7	447.7	389.2
March 31,	413.7	447.7	405.0
April 1,	413.7	447.7	385.5
April 2,	408.2	444.5	406.9

Ten-day Averages.

	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.
January 22-31,	412.5	442.5	396.3
January 23-February 1,	412.9	444.1	396.9
January 24-February 2,	413.7	444.2	398.4
January 25-February 3,	414.5	445.6	399.3
January 26-February 4,	414.6	445.5	400.1
January 27-February 5,	415.7	446.3	401.1
January 28-February 6,	416.7	446.1	397.6
January 29-February 7,	418.6	446.7	399.4
January 30-February 8,	418.0	447.3	398.1
January 31-February 9,	419.4	447.6	399.2
February 1-10,	419.9	449.0	397.3
February 2-11,	421.0	448.8	398.2
February 3-12,	420.5	448.7	396.7
February 4-13,	420.8	448.3	398.7
February 5-14,	421.2	448.7	397.5
February 6-15,	420.1	447.3	398.5
February 7-16,	421.3	448.5	400.6
February 8-17,	419.7	448.0	401.0
February 9-18,	421.0	448.5	401.1
February 10-19,	419.8	447.2	401.4
February 11-20,	420.6	446.3	402.0

Ten-day Averages—Continued.

	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.
February 12-21,	421.1	445.6	401.9
February 13-22,	421.2	445.5	401.7
February 14-23,	420.8	445.4	401.4
February 15-24,	421.3	444.9	400.5
February 16-25,	421.3	445.4	400.5
February 17-26,	420.4	444.8	399.7
February 18-27,	419.9	444.9	398.3
February 19-28,	419.1	444.6	398.0
February 20-March 1,	418.7	444.6	396.7
February 21-March 2,	418.1	444.8	396.8
February 22-March 3,	416.3	445.4	395.5
February 23-March 4,	417.2	445.5	396.7
February 24-March 5,	417.3	445.3	394.5
February 25-March 6,	415.8	445.9	395.4
February 26-March 7,	416.5	445.6	395.7
February 27-March 8,	416.6	445.2	395.6
February 28-March 9,	417.8	444.4	396.0
March 1-10,	417.7	443.7	395.7
March 2-11,	418.6	443.4	396.9
March 3-12,	418.1	442.9	396.2
March 4-13,	419.0	442.3	396.9
March 5-14,	416.9	442.0	395.2
March 6-15,	417.9	441.9	397.9
March 7-16,	417.0	441.3	397.3
March 8-17,	416.6	441.2	396.8
March 9-18,	415.5	441.8	397.0
March 10-19,	414.2	442.0	396.5
March 11-20,	413.1	442.8	396.6
March 12-21,	412.2	443.5	396.4
March 13-22,	411.1	444.2	395.8
March 14-23,	410.4	444.2	396.0
March 15-24,	409.5	444.4	396.0
March 16-25,	408.8	444.1	395.1
March 17-26,	408.4	444.8	394.2
March 18-27,	409.0	445.6	395.0
March 19-28,	408.7	446.1	395.7
March 20-29,	410.1	446.9	396.6
March 21-30,	410.7	447.0	396.7
March 22-31,	411.0	447.3	396.6
March 23-April 1,	412.0	447.2	396.8
March 24-April 2,	411.7	447.6	397.2

These results are represented graphically in the right hand portion of Plate I in the same manner as those of Experiment I. The plate shows a prompt and rather rapid increase in weight, following the change in feed. Apparently this increase was due simply to the greater amount of the new ration, since it was followed after a longer or shorter time by a gradual and steady diminution of weight. During the first fifteen days of the new feeding, the average gain per day and head was:

Steer 1,	0.67 kgs.
Steer 2,	1.27 kgs.
Steer 3,	0.47 kgs.

In other words, if the effects of the feed had been judged of from the first fifteen days, the ration would have appeared to be sufficient to cause a very considerable production, while as a matter of fact the subsequent weighings showed that it was insufficient for maintenance. These figures throw an interesting light upon conclusions drawn from changes in live weight during short periods, especially immediately after a change of feed.

Following the first increase in live weight, fluctuations occur which render an exact interpretation of the results difficult. On the whole, however, there appears to have been a slight falling off in the case of each animal, but the exact amount is not so easily determined. It has been more or less customary, in experiments of this character, to regard the difference between the final (average) live weight and that at the beginning of the experiment (usually exclusive of a preliminary period) as representing the gain or loss due to the feeding. In this case, however, it is evident that the first and last averages have no greater validity than those of a few days earlier or later, and a glance at the plate makes evident that the apparent loss per day may be very materially modified by a judicious choice of the averages to be compared.

It is believed, therefore, that a more accurate idea of the real rate of loss may be obtained by the graphic method. Accordingly the broken line in the chart has been drawn to represent the general course of the live weight, and the rate of loss computed from its indications. Of course, the location of this line represents to a degree the individual judgment of the experimenter, but it is a judgment in view of all the facts in the case and therefore seems likely to approximate the truth more closely than a mechanical comparison of two weights or averages which must be arbitrarily selected.

Comparing the actual average weights for certain days on which they correspond with those indicated by the assumed line, we find the following as the average loss per day:

Steer 1.		Steer 2.		Steer 3.	
February 5-14, ...	421.2 kgs.	February 4-13, ...	445.3 kgs.	Jan. 26-Feb. 4, ..	400.1 kgs.
March 22-31, ...	411.0 kgs.	March 16-25, ...	441.1 kgs.	March 22-31, ...	396.6 kgs.
Loss, ...	10.2 kgs.	Loss, ...	4.2 kgs.	Loss, ...	3.5 kgs.
Loss per day, ...	0.222 kgs.	Loss per day, ...	0.102 kgs.	Loss per day, ...	0.063 kgs.

Estimating the composition of this loss of weight as in the previous experiment, we have per day and head:

	Steer 1. Grms.	Steer 2 Grms.	Steer 3. Grms.
Gain of nitrogen, ...	1.76	4.23	4.62
Equivalent "flesh,"	49.58	119.1	130.1
Loss of weight, ...	222.00	102.0	63.0
Computed loss of fat, ...	271.58	221.1	193.1

Estimated Production of Methan.

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Crude fiber digested,	706	861	753
Nitrogen-free extract digested,	1,316	1,478	1,249
Total,	2,022	2,334	2,002
Estimated methan,	92.0	106.8	91.1
	Cal.	Cal.	Cal.
Equivalent energy,	1,219	1,407	1,206

Using the same data as before, we obtain the following figures for the balance of energy:

Energy per Day and Head.

	Steer 1.		Steer 2.		Steer 3.	
	Ingesta. Cal.	Egesta. Cal.	Ingesta. Cal.	Egesta. Cal.	Ingesta. Cal.	Egesta. Cal.
Food,	20,898		20,898		20,898	
Loss from body:						
Fat (computed),	2,576		2,097		1,832	
Excreta:						
Feces,		11,033		9,343		11,090
Urine (computed),		472		488		442
Methan (computed),		1,219		1,407		1,206
Gain by body:						
Proteids,		63		151		165
For maintenance,		10,687		11,606		9,827
	23,474	23,474	22,995	22,995	22,730	22,730

Maintenance Ration per Day.

	Average live weight.* Kgs.	Energy.	
		Per head. Cal.	Per 500 kgs. live weight. Cal.
Steer 1,	420	10,687	12,000
Steer 2,	450	11,606	12,460
Steer 3,	400	9,827	11,400

EXPERIMENTS OF 1893-94.

ANIMALS.

The same three steers which served for the experiments of the previous year were used in these experiments also. They were on mountain pasture during the summer and when brought in, in October, had increased somewhat in weight, No. 1 having gained about 30 kgs., No. 2, about 10 kgs. and No. 3 about 20 kgs.

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*The same average live weights are taken as in the previous experiment, since the surface of the animals, upon which the computation is really based, cannot have materially changed.

GENERAL PLAN OF EXPERIMENTS.

Upon the basis of the results of the previous year it was proposed to feed a maintenance ration which should contain grain in place of a portion of the hay previously used. During the first period, the grain employed was corn (maize) meal; during the second period, old process linseed meal. A third period was subsequently added in which the animals were fed exclusively on cotton-seed feed, a product which was at that time being pushed in Pennsylvania markets and which was claimed to consist of one part cotton-seed meal and five parts of hulls.

METHODS.

The methods employed were substantially the same as those of the previous year, except that the animals were weighed daily after watering, as well as before, and the amount of water consumed thus determined. The experimental day was regarded as closing with the weighing of the animal and the watering as the first act of the succeeding day. The weight of water consumed is accordingly recorded as of the same date as the next succeeding live weight of the animal, and is so represented in the plates, although separated from it by an interval of almost 24 hours. The amount of potential energy contained in the urine was also determined in these experiments in the manner described below.

FEEDS USED.

The hay used was nearly clear timothy (*Phleum pratense*), all taken from the same mow. A sample was taken for analysis during the digestion week of each period and the results are given in full in connection with those on digestibility. The following table gives the composition of the dry matter of the several feeds used.

Percentage Composition.

	Timothy hay. I.	Timothy hay. II.	Corn meal.	Linseed meal.	Cotton-seed feed.
Ash,	4.58	5.03	1.33	5.81	2.93
Proteids,	7.36	7.17	9.63	36.59	9.69
Nitrogen-free extract,	48.79	50.44	82.39	42.67	46.77
Non-proteids,	0.30	0.27	0.09	2.62	.00
Crude fiber,	36.76	34.95	2.58	10.05	37.44
Ether extract,	2.21	2.15	3.98	2.26	3.17
	100.00	100.00	100.00	100.00	100.00

The results of the experiments were far from satisfactory. The digestibility of the mixed rations of the first two experiments was considerably lower than was anticipated and the results of the degestion trials show certain abnormal features. Moreover, the fluctuations of the live weight were such as to render the interpretation of the results difficult. The experiments are reported, in a somewhat abridged form, for the sake of a complete record, and not because much confidence is felt in their results.

Experiment III.

November 16, 1893 to January 5, 1894—51 Days.

From October 6th to November 15th, inclusive, the animals were fed 5.444 kgs. (12 lbs.) of timothy hay per day and head. On Nov. 16th the addition of corn meal was begun, the feed on the several days being as follows:

	Timothy hay. Kgs.	Corn meal. Kgs.
November 16,	5.444	0.455
November 17,	5.444	0.455
November 18,	5.444	0.682
November 19,	5.444	0.682
November 20,	5.444	0.909
November 21,	2.948	1.474

The ration of November 21st was continued through the experiment, except in the case of Steer No. 3, which became ill during the digestion period and was fed a ration of hay and bran until he recovered.

DIGESTIBILITY.

The percentage digestibility was determined for the seven days, Dec. 16-22, 1893, inclusive. The weights and composition of the excreta on those days were as follows:

	Feces.		Urine.		
	Fresh weight. Grms.	Air-dry weight. Grms.	Weight. Grms.	Nitrogen. Per cent.	Weight of nitrogen. Grms.
STEER 1:					
December 16th,	9,769	1,893	3,629	0.677	24.57
December 17th,	10,370	2,096	3,454	0.777	26.84
December 18th,	9,140	1,707	4,434	0.784	34.76
December 19th,	11,720	2,321	3,126	0.907	28.35
December 20th,	8,818	1,812	3,014	0.988	29.78
December 21st,	9,574	1,895	2,630	0.974	25.62
December 22d,	9,790	1,998	3,874	0.845	32.74
Total,	69,181	13,721	24,161	....	202.66
STEER 2:					
December 16th,	9,664	1,892	4,448	0.528	23.49
December 17th,	6,364	1,491	4,888	0.528	28.94
December 18th,	9,042	2,110	4,518	0.674	30.45
December 19th,	6,812	1,503	4,070	0.613	24.95
December 20th,	7,322	1,705	3,504	0.590	20.67
December 21st,	5,713	1,102	5,028	0.716	36.00
December 22d,	9,490	1,998	4,210	0.801	33.72
Total,	54,407	11,801	30,666	....	198.22

Percentage Composition.

	Timothy hay	Corn meal.	Feces.	
			Steer 1.	Steer 2.
Loss in air-drying,	7.60	10.75	....	....
Composition, air-dry:				
Water,	4.94	2.60	3.68	3.34
Ash,	4.35	1.30	5.73	6.12
Proteids,	7.00	9.38	7.31	7.69
Non-proteids,	0.28	0.98		
Crude fiber,	34.94	2.51	47.72	44.12
Nitrogen-free extract,	46.39	80.24	33.40	36.51
Ether extract,	2.10	3.88	2.16	2.22
	100.00	100.00	100.00	100.00
Total nitrogen,	1.165	1.515	1.170	1.230
Composition of dry matter:				
Ash,	4.58	1.33	5.95	6.33
Proteids,	7.36	9.63	7.59	7.96
Non-proteids,	0.30	0.09		
Crude fiber,	36.76	2.58	49.55	45.65
Nitrogen-free extract,	48.79	82.39	34.67	37.76
Ether extract,	2.21	3.98	2.24	2.30
	100.00	100.00	100.00	100.00
Total nitrogen,	1.226	1.556	1.215	1.273
Energy per gram of dry matter,	Cal. 4.442	Cal. 4.399	Cal. 4.764	Cal. 4.699

The percentage digestibility, on the basis of the above figures, was as follows:

Per Day and Head.

	Fresh substance. Grams.	Dry matter. Grams.	Ash. Grams.	Organic matter. Grams.	Total N x 6.25. Grams.	Proteids. Grams.	Non-proteids.* Grams.	Crude fiber. Grams.	Nitrogen-free extract. Grams.	Ether extract. Grams.	Energy. Cal.
STEER 1:											
Hay,	2,948	2,589	119	2,470	198	191	7	952	1,263	57	11,500
Corn meal,	1,474	1,281	17	1,264	125	124	1	33	1,055	51	5.635
Total eaten,	4,422	3,870	136	3,734	323	315	8	985	2,318	108	17,135
Feces,	9,883	1,888	112	1,776	143	143	0	936	655	42	8,994
Digested,	....	1,982	24	1,958	180	172	8	49	1,663	66	8,141
Per cent. digested,	....	51.22	17.65	52.44	55.73	54.60	100	4.97	71.75	61.11	47.52
Nutritive ratio, 1:10.9.											
STEER 2:											
Total eaten as above,	4,422	3,870	136	3,734	323	315	8	985	2,318	108	17,135
Feces,	7,772	1,630	103	1,527	130	130	0	744	615	38	7,659
Digested,	....	2,240	33	2.207	193	185	8	241	1,703	70	9,476
Per cent. digested,	....	57.88	24.26	59.10	59.75	58.73	100	24.47	73.47	64.81	55.31
Nutritive ratio, 1:11.4.											
SUMMARY OF COEFFICIENTS:											
Steer 1,	....	51.22	17.65	52.44	55.73	54.60	100	4.97	71.75	61.11	47.52
Steer 2,	....	57.88	24.26	59.10	59.75	58.73	100	24.47	73.47	64.81	55.31

*Assumed to be wholly digestible.

According to the above figures, the organic matter of the mixture of hay and corn meal was scarcely more digestible than that of the hay alone in the previous year's experiments. The proteids of the mixed ration were digested somewhat more completely than those of the hay, and the nitrogen-free extract very much more so, but the digestibility of the crude fiber was so low as to nearly offset these differences. The latter result is remarkable and not readily explicable. It is true that corn meal contains large amounts of starch and that this substance, when added to a ration, has been frequently observed to depress the digestibility of the crude fiber, although never to this extent. In the corn meal, however, the starch is accompanied by a reasonable amount of proteids and the nutritive ratio of the corn is slightly narrower than that of the hay, so that the effect of mixing the two is to narrow the nutritive ratio as compared with an exclusive hay ration. Moreover, an even more striking result of the same sort showed itself in the succeeding experiment (IV) in which the corn meal was replaced by linseed meal, a feeding stuff rich in proteids and relatively poor in non-nitrogenous matters. The analyses of feed and feces were carefully made,.and the results of duplicate determinations were concordant, but even the assumption of an analytical error in the determinations of crude fiber fails to account for the abnormally low digestibility of the total dry matter. Neither is there any indication in the live weight of any considerable retention of feces, although in the case of steer No. 3, which suffered from a slight impaction, the resulting increase in weight was quite marked. Steer No. 2 showed a higher digestive power than No. 1, as was the case with the second experiment of the previous year, the difference being about the same.

PROTEID METABOLISM.

The following figures show the proteid metabolism per day and head for the digestion period, expressed in terms of nitrogen. Steer 1 was apparently very nearly in equilibrium as regards nitrogen, while Steer 2, with a somewhat greater supply of digestible proteids, metabolized no more than Steer 1, and consequently made a slight gain. This difference may perhaps be explained, if we accept the results on digestibility, by the greater amount of non-nitrogenous matter digested. It is not improbable that some loss of nitrogen may have occurred, in this and the next succeeding experiment, in the airdrying of the feces, since the animals ate a considerable proportion of grain. If this was the case, the loss of proteids from the body was, of course, somewhat greater than that shown in the table.

	Steer 1.		Steer 2.	
	Grms.	Grms.	Grms.	Grms.
Nitrogen in food,		51.67		51.67
Nitrogen in feces,	22.94		20.74	
Nitrogen in urine,	28.95		28.32	
Nitrogen in total excretion,		51.89		49.06
Difference,		—0.22		+2.61
Equivalent proteids,		—1.38		+16.31

ENERGY OF EXCRETA.

In order to secure more exact figures for the metabolism of energy than could be obtained from estimates based upon the composition of the excreta, the total energy contained in the latter was determined in the following manner:

1-100 of the daily excretion of feces was air-dried at about 60 degrees C., the same aliquot of the daily excretion of urine added, and the whole again dried at a temperature not exceeding 60 degrees. In the air-dried residue the total nitrogen was determined as a check upon any loss occurring in the drying, and determinations of the energy of the mixed feces and urine and also of the feces alone were made,.as in the previous year's experiments. The weights of the excreta have already been given in connection with the digestion work. The air-dry weights and the content of the air-dry material in nitrogen and energy were as follows:

	Steer 1.	Steer 2.
Air-dry excreta:	Grms.	Grms.
December 16,	2,295	2,202
December 17,	2,486	1,692
December 18,	2,111	2,210
December 19,	2,408	1,598
December 20,	2,106	1,806
December 21,	2,102	1,406
December 22,	2,294	2,407
Average,	2,257	1,903
Nitrogen in air-dry matter, per cent.,	1.870	2.190
Energy per gram, air-dry, Cal.,	4.446	4.427

On the assumption that the loss of nitrogen in the mixed samples during drying was caused by the decomposition of urea, and estimating the heat of combustion of urea at 2.536 Cal.* per gram, equivalent to 5.434 Cal. per gram of nitrogen, we have the following results for the total energy of the excreta:

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*Average of determinations by Berthelot and by Stohmann and Langbein; U. S. Department Agr., Office of Exp. Stations, Bul. 21, p. 127.

Energy of Excreta.

	Steer 1.	Steer 2.
	Grms.	Grms.
Total nitrogen of daily excreta,	51.89	49.06
Nitrogen of air-dried excreta,	42.21	41.68
Loss of nitrogen,	9.68	7.38
	Cal.	Cal.
Energy of equivalent urea,	53	40
Energy of air-dry excreta,	10,035	8,422
Total energy of excreta,	10,088	8,462

The above figures permit also a computation of the potential energy of the urine, as follows:

Energy of Urine.

	Steer 1.	Steer 2.
	Cal.	Cal.
Total energy of excreta,	10,088	8,462
Energy of feces,	8,994	7,659
Energy of urine,	1,094	803
Energy of urine per gram of nitrogen,	37.79	28.35

No determinations of hippuric acid in the urine were made but a very simple calculation serves to show that, on any reasonable assumptions, the energy of the hippuric acid and urea present is not over one-half to three-fourths of the total energy of the urine, a result entirely in accord with those of other experimenters.

LIVE WEIGHTS.

The following table contains the daily weights of the steers and of the water consumed, together with ten-day averages computed as in the previous experiments, and the same results are represented graphically on Plates II, III and IV in the same manner as before:

Day ending at 1 P. M.	Weight Before Watering.			Water Consumed.		
	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.
November 16th,	460.6	492.6	435.5	....	....	....
November 17th,	467.2	478.6	437.7	....	....	....
November 18th,	460.4	480.8	427.3	....	....	....
November 19th,	465.4	469.5	440.9	....	....	....
November 20th,	458.8	475.9	421.4	....	....	....
November 21st,	457.2	475.9	421.4	....	....	....
November 22d,	456.3	462.9	428.9	....	....	....
November 23d,	447.0	473.1	416.4	....	....	....
November 24th,	459.1	469.0	430.9	....	....	....
November 25th,	451.3	467.2	419.6	....	....	....
November 26th,	445.4	453.6	410.1	....	....	....
November 27th,	460.9	464.3	431.8	21.8	19.7	23.1
November 28th,	451.3	455.2	416.6	0.0	0.0	0.0
November 29th,	448.6	465.9	419.6	5.4	15.2	14.5
November 30th,	444.5	453.6	412.8	6.4	1.4	5.0
December 1st,	450.4	467.2	421.8	15.4	22.7	18.6
December 2d,	450.0	456.8	423.7	9.5	0.0	14.1
December 3d,	457.9	457.9	426.6	17.2	19.5	15.4
December 4th,	445.9	454.3	415.9	0.0	0.0	0.0
December 5th,	451.8	465.0	427.3	19.1	20.6	10.4
December 6th	448.2	454.5	417.8	6.4	.0	2.2
December 7th,	439.5	469.5	427.3	0.5	24.5	28.1
December 8th,	452.9	453.6	413.7	22.7	.0	.0
December 9th,	449.5	474.0	438.6	7.9	31.8	46.3
December 10th,	449.1	460.9	424.1	10.4	.0	.0
December 11th,	440.4	468.1	435.5	.0	20.0	23.2
December 12th,	447.9	461.3	431.4	23.1	11.3	9.5
December 13th,	453.1	467.7	438.9	18.4	21.8	22.2
December 14th,	444.5	455.9	429.1	7.3	.0	1.6
December 15th,	456.8	465.9	429.1	22.7	22.7	5.0
December 16th,	444.1	460.4	430.5	0.0	9.1	17.7
December 17th,	447.2	469.5	446.8	14.1	18.6	29.9
December 18th,	444.5	467.2	435.0	10.9	13.2	5.0
December 19th,	446.8	464.9	442.3	13.6	11.3	27.7
December 20th,	435.4	462.2	430.0	.0	9.1	13.6
December 21st,	450.4	466.3	435.0	26.3	18.6	23.6
December 22d,	448.6	465.4	419.6	10.9	11.3	.0
December 23d,	443.6	468.6	427.7	6.4	12.2	25.4
December 24th,	446.3	452.2	412.8	15.4	0.0	0.0
December 25th,	449.1	475.4	421.8	15.4	23.1	22.7
December 26th,	453.1	461.3	408.2	16.8	0.0	0.0
December 27th,	448.2	469.5	410.1	8.2	19.5	10.4
December 28th,	449.5	456.3	422.8	15.9	0.0	24.9
December 29th,	447.2	467.2	412.8	10.9	20.4	0.0
December 30th,	458.2	468.1	415.0	27.9	10.4	11.8
December 31st,	449.1	454.5	410.5	4.5	0.0	8.2
January 1st,	451.8	468.6	415.9	15.9	20.4	15.0
January 2d,	446.8	461.3	408.2	7.8	6.8	2.7
January 3d,	450.4	452.7	416.6	16.3	0.0	21.2
January 4th,	450.9	465.4	406.9	14.5	25.9	3.2
January 5th,	450.9	451.3	416.9	19.1	0.0	23.1

Ten-day Averages.

Date.	Weight Before Watering.			Water Consumed.		
	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.
November 16-25,	458.3	474.6	428.0	....	....	....
November 17-26,	456.8	470.7	425.5	....	....	....
November 18-27,	456.2	469.2	424.9	....	....	....
November 19-28,	455.3	466.7	424.1	....	....	....
November 20-29,	453.6	466.3	422.0	....	....	....
November 21-30,	452.2	464.1	421.1	....	....	....
November 22-December 1,	451.5	463.2	421.2	....	....	....
November 23-December 2,	450.9	462.6	420.6	....	....	....
November 24-December 3,	451.9	461.1	421.7	....	....	....
November 25-December 4,	450.6	459.6	420.2	....	....	....
November 26-December 5,	450.7	459.4	420.9	....	....	....
November 27-December 6,	451.0	459.5	421.7	10.13	9.91	11.34
November 28-December 7,	448.8	460.0	421.2	7.99	10.29	10.84
November 29-December 8,	449.0	459.8	420.7	10.26	10.39	10.84
November 30-December 9,	449.1	460.6	422.6	10.51	12.05	14.02
December 1-10,	449.5	461.4	423.7	10.91	11.91	13.52
December 2-11,	448.5	461.5	425.1	9.37	11.64	13.88
December 3-12,	448.3	461.1	425.8	10.73	12.77	13.42

Ten-day Averages—Continued.

Date.	Weight Before Watering.			Water Consumed.		
	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.
December 4-13,	447.8	463.9	427.1	10.85	13.00	14.10
December 5-14,	447.7	463.1	428.4	11.58	13.00	14.26
December 6-15,	448.2	463.1	428.6	11.94	13.21	13.72
December 7-16,	447.8	463.7	429.8	11.30	14.12	15.26
December 8-17,	448.6	463.7	431.8	12.66	13.53	15.44
December 9-18,	447.7	465.1	433.9	11.48	14.85	15.94
December 10-19,	447.4	464.2	434.3	12.06	12.80	14.08
December 11-20,	446.1	464.3	434.9	11.01	13.71	15.44
December 12-21,	447.1	464.1	434.8	13.64	13.57	15.58
December 13-22,	447.1	464.5	433.6	12.42	13.57	14.63
December 14-23,	446.2	464.6	432.5	11.22	12.61	14.95
December 15-24,	446.4	464.3	430.9	12.03	12.63	14.79
December 16-25,	445.6	465.2	430.2	11.80	13.65	16.57
December 17-26,	446.5	465.3	427.9	12.98	12.74	14.80
December 18-27,	446.6	465.3	424.3	12.39	12.83	12.85
December 19-28,	447.1	464.2	423.0	12.89	11.51	14.84
December 20-29,	447.1	464.4	420.1	12.63	12.42	12.07
Decebmer 21-30,	449.4	465.0	418.6	15.41	12.55	11.89
December 22-31,	449.3	463.9	416.1	13.23	10.69	10.35
December 23-January 1,	449.6	464.2	415.8	13.73	11.60	11.85
December 24-January 2,	449.9	463.4	413.8	13.82	11.06	9.58
December 25-January 3,	450.3	463.5	414.2	13.91	11.06	11.71
December 26-January 4,	450.5	462.5	412.7	13.82	10.34	9.75
December 27-January 5,	450.3	461.5	413.6	14.05	10.34	12.06
December 28-January 6,	450.9	461.1	414.0	15.32	11.07	12.24
December 29-January 7,	449.9	460.5	412.5	13.91	11.07	10.57
December 30-January 8,	451.3	460.1	412.3	15.47	11.39	12.02
December 31-January 9,	450.3	458.5	411.3	13.29	10.35	11.48

The tables and plates show a considerable falling-off in weight at the beginning of the experiment, which was quite evidently due to the decrease in the bulk of the ration, due to the withdrawal of a part of the hay. After that time the fluctuations of the average weight are such as to render its interpretation difficult.

As already noted, No. 3 became ill during the digestion trial, probably with a slight impaction, and was temporarily dropped from the experiment. Assuming the broken black lines in the plates to represent the average change in live weight of the other two steers, and that the fluctuations above and below this were due to variations in excretion, we may make some approximate computation of the gain or loss by the animals. Of course, as previously pointed out, this assumption is largely a matter of judgment and the results could be very considerably varied by differences in this respect, particularly when the weights vary so irregularly as in this case. The following computation is presented as simply an estimate and is made upon the same basis as those of the previous year, the average live weights at the beginning and close of the experiment being taken from the plates.

Loss of Live Weight.

	Steer 1. Kgs.	Steer 2. Kgs.
November 22d-December 1, 1893,	452.2	463.0
January 1st-10th, 1894,	446.5	461.5
Loss,	5.5	1.5
Loss per day,	0.134	0.034

The methods of computation employed in the previous experiments yield the following results, the energy of the total excreta being in this case the result of direct determinations.

Per Day and Head.

	Steer 1. Gms.	Steer 2. Gms.
Gain or loss of nitrogen,	—0.22	+2.61
Equivalent "flesh,"	—6.20	+73.43
Gain or loss of weight,	—134.00	—34.00
Computed gain or loss of fat,	—127.80	—107.43

Estimated Production of Methan.

	Steer 1. Gms.	Steer 2. Gms.
Crude fiber digested,	49	241
Nitrogen-free extract digested,	1,633	1,703
Total,	1.712	1,944
Estimated methan,	77.9	88.5
	Cal.	Cal.
Equivalent energy,	1,031	1,171

Energy per Day and Head.

	Steer 1.		Steer 2.	
	Ingesta. Cal.	Egesta. Cal.	Ingesta. Cal.	Egesta. Cal.
Food,	17,135	....	17,135	....
Loss from body:				
Proteids,	8	....	....	....
Fat (estimated),	1,213	....	1,020	....
Excreta:				
Feces and urine,	....	10,088	....	8,462
Methan (estimated),	....	1,031	....	1,171
Gain by body:				
Proteids,	....	....	....	93
For maintenance,	....	7,237	....	8,429
	18,356	18,356	18,155	18,155

The results are strikingly at variance with those of 1892-3, as well as with those of later experiments, and, taken in connection with the equally remarkable digestion results, appear to warrant us in rejecting both as abnormal.

Experiment IV.

January 6th to March 16th, 1894.—70 Days.

In this experiment, new process linseed meal was gradually substituted for corn meal, as shown below, the amount of hay remaining the same.

	Corn meal. Kgs.	Linseed meal. Kgs.
January 6,	1.361	0.113
January 7,	1.135	0.339
January 8,	0.907	0.567
January 9,	0.680	0.794
January 10,	0.454	1.020
January 11,	0.339	1.135
January 12,	0.227	1.247
January 13,	0.113	1.361
January 14,	....	1.474
January 15,	....	1.678

Steer No. 3 seeming to show a tendency to decrease in weight, his ration was increased, January 22d, to

Hay,	3.629 kgs.
Linseed meal,	1.814 kgs.

DIGESTIBILITY.

The special digestion trial covered the period from February 21-27, inclusive, and gave the following results:

Excretion.

	Feces.		Urine.		
	Fresh weight. Grms.	Air-dry weight. Grms.	Weight. Grms.	Nitrogen. Per cent.	Weight of nitrogen. Grms.
STEER 1:					
February 21,	13.000	2,700	3,818	1.94	74.07
February 22,	14,496	2,999	3,972	2.125	84.41
February 23,	15.888	3,098	3,140	2.065	64.85
February 24,	6,580	(1,542)	2,636	2.24	59.06
February 25,	13,818	2,802	4,301	1.945	83.66
February 26,	13,492	2,599	3,146	2.24	70.47
February 27,	14,144	2,908	3,524	2.60	91.62
Total,	84,838	17,106	21,901	....	528.13
STEER 2:					
February 21,	15,490	2,798	5,832	1.31	76.40
February 22,	11,364	2,193	3,748	1.65	61.84
February 23,	13,902	2,800	3,896	1.90	74.01
February 24,	14,699	2,799	4.496	1.78	80.03

Excretion—Continued.

	Feces.		Urine.		
	Fresh weight. Grms.	Air-dry weight. Grms.	Weight. Grms.	Nitrogen. Per cent.	Weight of nitrogen. Grms.
February 25,	13,602	2,400	2,168	1.78	38.59
February 26,	13,231	2,506	4,464	1.61	71.87
February 27,	10,182	2,096	4,175	1.93	80.58
Total,	92,470	17,592	28,778	....	483.22
STEER 3:					
February 21,	13,049	2,409	2,699	1.885	50.88
February 22,	17,462	2,993	3,573	2.04	72.89
February 23,	19,518	3,474	3,762	2.00	75.24
February 24,	16,763	2,795	2,979	2.15	64.06
February 25,	15,042	2,508	3,337	2.09	69.74
February 26,	14,378	2,397	3,909	1.975	77.21
February 27,	17,098	2,999	4,773	1.86	88.78
Total,	113,310	19,575	25,032	....	498.79

Percentage Composition of Food and Excreta.

			Feces.		
	Timothy hay.	Linseed meal.	Steer 1.	Steer 2.	Steer 3.
Loss in air-drying,	6.10	4.40	....	....	....
Composition, air-dry:					
Water,	5.03	5.55	4.71	4.54	4.73
Ash,	4.78	5.49	6.50	6.33	6.26
Proteids,	6.81	34.56	8.33	9.44	9.16
Non-proteids,	0.26	2.47			
Crude fiber,	33.19	9.49	43.74	42.04	39.85
Nitrogen-free extract,	47.90	40.31	35.08	36.07	38.55
Ether extract,	2.04	2.13	1.64	1.58	1.45
	100.00	100.00	100.00	100.00	100.00
Total nitrogen,	1.130	5.925	1.333	1.510	1.465
Composition of dry matter:					
Ash,	5.03	5.81	6.81	6.63	6.57
Proteids,	7.17	36.59	8.74	9.89	9.61
Non-proteids,	0.27	2.62			
Crude fiber,	34.94	10.05	45.91	44.04	41.83
Nitrogen-free extract,	50.44	42.67	36.82	37.78	40.47
Ether extract,	2.15	2.26	1.72	1.66	1.52
	100.00	100.00	100.00	100.00	100.00
Total nitrogen,	1.190	6.273	1.399	1.582	1.538
	Cal.	Cal.	Cal.	Cal.	Cal.
Energy per gram of dry matter,	4.153	4.634	4.726	4.810	4.657

From the above data, the percentage digestibility is computed as follows:

Per Day and Head.

	Fresh substance. Grams.	Dry matter. Grams.	Ash Grams.	Organic matter. Grams.	Total N x 6.25. Grams.	Proteids. Grams.	Non-proteids. Grams.	Crude fiber. Grams.	Nitrogen-free extract. Grams.	Ether extract. Grams.	Energy. Cal.
STEER 1:											
Hay eaten,	2,948	2,629	132	2,497	196	189	7	919	1,325	57	11,865
Linseed meal eaten,	1,678	1,515	88	1,427	594	554	40	152	647	34	7,021
	4,626	4,144	220	3,924	790	743	47	1,071	972	91	18,886
Feces,	14,140	2,717	185	2,532	238	238	....	1,247	1,000	47	12,841
Digested,	....	1,427	35	1,392	552	505	47	?	972	44	6,045
Per cent. digested,	....	34.44	15.91	35.47	69.87	67.97	100.00	?	49.29	48.35	32.00
STEER 2:											
Hay eaten,	2,948	2,629	132	2,497	196	189	7	919	1,325	57	11,865
Linseed meal eaten,	1,678	1,515	88	1,427	594	554	40	152	647	34	7,021
	4,626	4,144	220	3,924	790	743	47	1,071	1,972	91	18,886
Feces,	13,210	2,399	159	2,240	237	237	....	1,057	906	40	11,539
Digested,	....	1,745	61	1,684	553	506	47	14	1,066	51	7,347
Per cent. digested,	....	42.11	27.73	42.92	70.00	68.11	100.00	1.31	54.06	56.04	38.90
STEER 3:											
Hay eaten,	3,629	3,236	163	3,073	241	232	9	1,131	1,631	70	14,604
Linseed meal eaten,	1,814	1,638	95	1,543	642	599	43	165	699	37	7,591
	5,443	4,874	258	4,616	883	831	52	1,296	2,330	107	22,195
Feces,	16,187	2,664	175	2,489	256	256	....	1,114	1,078	41	12,406
Digested,	....	2,210	83	2,127	627	575	52	182	1,252	66	9,789
Per cent. digested,	....	45.35	32.17	46.08	71.01	69.20	100.00	14.04	53.74	61.68	44.11

The percentage digestibility of the ration is strikingly low, especially in the case of Steer 1. In this case, the very low figures, together with the negative results on the crude fiber, seem to suggest that the amount of excretion during the digestion period was abnormally large, a suggestion which is perhaps further borne out by the very rapid decrease in live weight which began at that time. The same thing is true, although to a much less extent, of Steers 2 and 3.

PROTEID METABOLISM.

For the proteid metabolism we have the following results:

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Nitrogen in food,	126.33	126.33	141.26
Nitrogen in feces,	38.01	37.95	40.97
Nitrogen digested,	88.32	88.38	100.29
Nitrogen in urine,	78.18	69.04	71.26
Difference,	+10.14	+19.34	+29.03
Equivalent proteids,	+63.37	+120.87	+181.43

It is interesting to note that the above results do not seem to confirm the suggestion made above of an excessive excretion of feces. Although the feeding had been continued for considerably over a month, the nitrogen equilibrium seems not to have been reached, there being a very considerable apparent gain of nitrogen by the animals. It seems doubtful, however, whether so large a gain of nitrogen could have continued for so long, and the difficulty is increased if we are to suppose that the amount really digested was still larger than that computed in the table.

In view of these abnormalities and inconsistencies, as well as of the great fluctuation in live weight, as shown in the following table and by Plates II, III and IV, it seems evident that the results are of very questionable value, and further discussion of them appears superfluous.

Daily Weights.

Date.	Weight Before Watering.			Water Consumed.		
	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.	Steer 1. Kgs.	Steer 2. Kgs,	Steer 3. Kgs.
January 5, 1894,	450.9	451.3	416.9	19.1	0.0	23.1
January 6, 1894,	454.0	465.4	414.6	20.9	26.8	12.2
January 7, 1894,	440.0	450.4	407.8	1.8	.0	8.2
January 8, 1894,	460.4	463.6	410.5	26.5	23.6	14.5
January 9, 1894,	449.1	451.3	405.1	6.1	0.0	6.4
January 10, 1894,	447.9	459.0	408.2	10.9	18.1	15.0
January 11, 1894,	452.2	446.8	408.2	19.3	0.0	12.2
January 12, 1894,	447.2	465.4	412.8	11.8	29.5	18.1
January 13, 1894,	447.7	454.5	399.2	12.7	0.0	0.0
January 14, 1894,	451.3	453.6	418.2	18.6	18.2	33.1
January 15. 1894,	452.5	461.3	406.4	20.4	17.2	3.6
January 16, 1894,	455.0	459.5	410.5	18.4	10.4	20.0
January 17, 1894,	452.2	463.6	411.4	14.1	18.6	19.1
January 18, 1894,	452.0	449.1	410.5	14.5	0.0	16.3
January 19, 1894,	448.2	467.7	403.7	10.5	28.1	15.9
January 20, 1894,	457.7	453.6	399.2	24.7	0.0	8.6
January 21, 1894,	451.3	461.8	408.2	8.6	22.0	23.1
January 22, 1894,	458.2	446.8	417.8	21.8	0.0	23.6
January 23, 1894,	454.5	468.3	414.6	13.2	33.1	21.8
January 24, 1894,	457.7	453.6	414.1	19.5	.5	13.2
January 25, 1894,	449.5	466.3	413.2	8.6	26.3	16.8
January 26, 1894,	453.1	457.7	410.3	20.4	6.4	5.0
January 27, 1894,	447.7	456.3	415.0	10.0	13.6	21.5
January 28, 1894,	448.2	443.2	411.0	13.2	0.0	9.5
January 29, 1894,	446.8	462.0	413.7	15.9	30.8	22.2
January 30, 1894,	443.2	458.6	411.4	11.3	12.5	10.9
January 31, 1894,	450.0	453.6	419.6	21.8	20.4	24.0
February 1, 1894,	445.9	449.5	404.6	11.8	12.7	.9
February 2, 1894,	451.3	454.0	428.7	19.1	22.2	36.7
February 3, 1894,	455.4	457.7	411.0	22.2	21.8	0.0
February 4, 1894,	461.5	463.1	432.8	19.1	19.1	34.5
February 5, 1895,	457.7	458.6	412.1	14.7	14.5	0.0
February 6, 1894,	458.6	461.8	421.4	17.2	21.3	26.1
February 7, 1894,	457.2	460.4	418.0	13.6	15.0	14.1
February 8, 1894,	450.4	463.1	416.0	10.0	21.3	15.2
February 9, 1894,	450.9	462.2	415.5	15.0	13.6	15.0
February 10, 1894,	454.5	459.1	419.6	18.6	17.2	20.0
February 11, 1894,	454.0	462.2	412.8	11.3	20.4	6.8
February 12, 1894,	456.1	462.7	428.2	17.7	16.3	34.9
February 13, 1894,	451.3	458.2	411.9	9.8	13.2	0.0
February 14, 1894,	446.8	453.6	416.0	10.4	15.0	17.7
February 15, 1894,	448.2	455.4	416.0	16.8	19.1	16.3
February 16, 1894,	456.3	453.6	422.5	22.2	15.0	22.7
February 17, 1894,	450.9	462.2	408.2	8.6	24.5	0.0
February 18, 1894,	449.5	454.1	421.8	14.1	10.4	29.9
February 19, 1894,	453.6	460.0	427.8	20.9	23.6	27.2
February 20, 1894,	449.1	464.5	417.8	11.8	18.6	8.2
February 21, 1894,	446.8	457.7	414.6	13.6	12.2	12.7
February 22, 1894,	447.2	467.0	418.9	15.9	24.5	24.5
February 23, 1894,	449.5	470.8	422.3	20.9	16.6	22.0
February 24, 1894,	446.8	466.8	429.8	5.4	14.5	29.0
February 25, 1894,	445.9	467.0	418.7	18.6	17.5	11.1
February 26, 1894,	433.6	458.2	420.7	7.7	13.4	22.7
February 27, 1894,	431.4	456.3	419.1	15.4	16.8	9.3
February 28, 1894,	428.7	454.1	417.8	14.5	19.1	7.2
March 1, 1894,	429.5	463.6	406.4	13.6	21.3	5.0
March 2, 1894,	431.6	464.7	411.9	16.3	15.0	17.7
March 3, 1894,	434.5	445.7	421.9	16.6	0.0	29.5
March 4, 1894,	428.6	460.4	403.7	9.1	29.3	5.4
March 5, 1894,	426.8	444.5	422.3	11.3	0.0	40.8
March 6, 1894,	428.6	455.9	402.3	10.0	26.3	4.1
March 7, 1894,	419.1	442.7	387.1	7.3	2.3	0.0
March 8, 1894,	416.8	446.3	416.9	11.6	17.2	44.5
March 9, 1894,	406.9	442.7	398.3	4.5	12.7	0.0
March 10, 1894,	420.7	434.1	387.4	30.4	7.7	2.7
March 11, 1894,	408.2	449.1	419.1	0.0	21.3	50.4
March 12, 1894,	433.6	447.7	403.2	35.4	13.6	0.0
March 13, 1894,	416.4	429.8	397.3	0.0	1.4	11.3
March 14, 1894,	414.6	451.6	409.1	8.2	37.4	29.9
March 15, 1894,	429.1	437.7	392.8	26.8	0.0	.9
March 16, 1894,	417.3	453.6	419.1	0.0	29.7	47.2

Ten-day Averages.

Date.	Weight Before Watering.			Water Consumed.		
	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.	Steer 1. Kgs.	Steer 2. Kgs,	Steer 3. Kgs.
January 1-10, 1894, ...	450.2	458.9	411.1	13.93	12.16	12.16
January 2-11, 1894, ...	450.3	456.7	410.3	14.27	10.12	11.88
January 3-12, 1894, ...	450.3	457.1	410.8	14.72	12.39	13.42
January 4-13, 1894, ...	450.0	457.3	409.0	14.36	12.39	11.29
January 5-14, 1894, ...	450.1	456.1	410.2	14.77	11.12	14.28
January 6-15, 1894, ...	450.2	457.1	409.1	14.90	12.85	12.33
January 7-16, 1894, ...	450.3	456.5	408.7	14.65	11.22	13.11
January 8-17, 1894, ...	451.6	457.9	409.1	15.88	13.06	14.29
January 9-18, 1894, ...	450.7	456.4	409.1	14.68	10.72	14.33
January 10-19, 1894, ...	450.6	458.1	409.0	15.12	13.53	15.33
January 11-20, 1894, ...	451.6	457.5	408.0	16.60	11.70	14.09
January 12-21, 1894, ...	451.5	459.0	408.0	15.43	13.90	15.78
January 13-22, 1894, ...	452.6	457.2	408.5	16.43	10.95	16.33
January 14-23, 1894, ...	453.2	458.5	410.1	16.48	14.27	18.51
January 15-24, 1894, ...	453.9	458.5	409.6	16.57	13.00	16.52
January 16-25, 1894, ...	453.6	459.0	410.3	15.39	13.91	17.84
January 17-26, 1894, ...	453.4	458.9	410.3	15.59	13.50	16.34
January 18-27, 1894, ...	453.0	458.1	410.7	15.18	13.00	16.58
January 19-28, 1894, ...	452.6	457.5	410.7	15.05	13.00	15.90
January 20-29, 1894, ...	452.5	457.0	411.7	15.59	13.29	16.53
Januayr 21-30, 1894, ...	451.0	457.0	412.9	14.25	14.54	16.76
January 22-31, 1894, ...	450.9	456.1	414.1	15.57	14.39	16.86
January 23-February 1, 1894, ...	449.7	456.4	412.8	14.57	15.66	14.59
January 24-February 2, 1894, ...	449.3	455.0	414.2	15.16	14.57	16.08
January 25-February 3, 1894, ...	449.1	455.4	413.9	15.43	16.69	14.76
January 26-February 4, 1894, ...	450.3	455.1	415.8	16.48	15.96	16.53
January 27-February 5, 1894, ...	450.8	455.2	415.9	15.91	16.76	16.03
January 28-February 6, 1894, ...	451.9	455.7	416.6	16.63	17.53	16.49
January 29-February 7, 1894, ...	452.8	457.4	417.3	16.67	19.03	16.95
January 30-February 8, 1894, ...	453.1	457.5	417.5	16.08	18.08	16.25
January 31-February 9, 1894, ...	453.9	458.4	417.9	16.45	18.20	16.06
February 1-10, 1894, ...	454.3	459.0	417.9	16.13	17.87	16.25
February 2-11, 1894, ...	455.2	460.2	418.7	16.08	18.64	16.84
February 3-12, 1894, ...	455.6	461.1	418.7	15.94	18.04	16.06
February 4-13, 1894, ...	455.2	461.1	418.8	14.70	17.19	16.06
February 5-14, 1894, ...	453.8	460.2	417.2	13.88	16.78	14.98
February 6-15, 1894, ...	452.8	459.9	417.5	14.04	17.25	16.61
February 7-16, 1894, ...	452.6	459.1	417.7	14.54	16.62	16.27
February 8-17, 1894, ...	451.9	459.2	416.7	14.04	17.57	14.84
February 9-18, 1894, ...	451.9	458.3	417.3	14.46	16.47	16.33
February 10-19, 1894, ...	452.1	458.1	418.5	15.04	17.47	17.55
February 11-20, 1894, ...	451.7	458.7	418.3	14.36	17.61	16.37
February 12-21, 1894, ...	450.9	458.2	418.5	14.59	16.79	16.96
February 13-22, 1894, ...	450.0	458.6	417.6	14.41	17.61	15.92
February 14-23, 1894, ...	449.8	459.9	418.6	15.52	17.95	18.12
February 15-24, 1894, ...	449.8	461.2	420.0	15.02	17.90	19.26
February 16-25, 1894, ...	449.6	462.4	420.2	15.20	17.74	18.74
February 17-26, 1894, ...	447.3	462.8	420.1	13.75	17.58	18.74
February 18-27, 1894, ...	445.3	462.2	421.2	14.43	16.81	19.08
February 19-28, 1894, ...	443.3	462.2	420.8	14.47	17.68	17.40
February 20-March 1, 1894, ...	440.9	462.6	418.6	13.74	17.45	15.18
February 21-March 2, 1894, ...	439.1	462.6	418.0	14.19	17.09	16.13
February 22-March 3, 1894, ...	437.9	461.4	418.8	14.49	15.87	17.81
February 23-March 4, 1894, ...	436.0	460.8	417.2	13.81	16.35	15.90
February 24-March 5, 1894, ...	433.7	458.1	417.2	12.85	14.69	17.78
February 25-March 6, 1894, ...	431.9	457.0	414.5	13.31	15.87	15.28
February 26-March 7, 1894, ...	429.2	454.6	411.3	12.18	14.85	14.17
February 27-March 8, 1894, ...	427.6	453.4	410.9	12.57	14.73	16.85
February 28-March 9, 1894, ...	425.1	452.1	408.9	11.48	14.32	15.42
March 1-10, 1894, ...	424.3	450.1	405.8	13.07	13.18	14.97
March 2-11, 1894, ...	422.2	448.6	407.1	11.71	13.18	19.51
March 3-12, 1894, ...	422.4	446.9	406.2	13.62	13.04	17.74
March 4-13, 1894, ...	420.6	445.3	403.8	11.96	13.18	15.97
March 5-14, 1894, ...	419.2	444.4	404.3	11.87	13.99	18.42
March 6-15, 1894, ...	419.4	443.8	401.4	13.42	13.99	14.42
March 7-16, 1894, ...	418.3	443.5	403.0	12.42	14.33	18.74
March 8-17, 1894, ...	418.4	443.3	404.8	13.14	14.10	18.74
March 9-18, 1894, ...	418.9	444.4	403.2	13.25	15.56	15.11
March 10-19, 1894, ...	421.9	444.8	406.0	15.52	14.29	19.10
March 11-20, 1894, ...	422.0	447.8	408.0	12.48	16.65	18.88
March 12-21, 1894, ...	424.3	447.7	408.7	14.95	14.52	17.37

Experiment V.

March 17th to April 21st, 1894.—36 Days.

This experiment was intended primarily to determine the digestibility of the so-called "Cotton-seed Feed" which was then being pushed in Pennsylvania markets. This material is claimed to consist of one part, by weight, of cotton-seed meal to five of hulls, mixed by machinery. The results of the experiments with this material, so far as they relate to its composition, digestibility and feeding value, have already been published in Bulletin No. 28 of this Station, and in its Annual Report for 1894, p. 44. The results are here presented somewhat in detail in their bearing on the question of maintenance.

The transition period from the previous feeding extended from March 17 to 22, inclusive, cottonseed feed being substituted for the oil meal at once and its amount gradually increased as follows:

	Steer 1.		Steer 2.		Steer 3.	
	Hay. Kgs.	Cotton-seed feed. Kgs.	Hay. Kgs.	Cotton-seed feed. Kgs.	Hay. Kgs.	Cotton-seed feed. Kgs.
March 17,	2.955	1.818	2.955	1.818	3.637	1.818
March 18,	2.955	2.728	2.955	2.728	3.637	2.728
March 19,	2.955	3.637	2.955	3.637	3.637	3.637
March 20,	2.955	4.546	2.955	4.546	3.637	4.546
March 21,	2.046	5.456	2.046	5.456	2.728	5.456
March 22,	1.136	6.364	1.136	6.364	1.818	6.364
March 23,	....	7.274	....	7.274	....	8.183

On March 31st, the ration fed to Nos. 1 and 2 was decreased to 6.364 kgs., it appearing that the live weight of these animals was increasing. As will be seen, however, subsequent results seem to indicate that this decrease in the ration was premature.

DIGESTIBILITY.

The digestion period covered the time from April 15 to 21 inclusive. The following tables contain the results:

Excretion.

	Feces.		Urine.		
	Fresh weight. Grms.	Air-dry weight. Grms.	weight. Grms.	Nitrogen. Per cent.	Weight of nitrogen. Grms.
STEER 1:					
April 15,	9,909	2,902	1,783	1.27	22.644
April 16,	12,881	3,495	2,098	1.36	28.533
April 17,	11,644	3,390	2,538	1.32	33.502
April 18,	14,518	3,804	1,958	1.07	20.951
April 19,	12,916	3,304	1,972	1.08	21.297
April 20,	13.582	3,396	2,179	1.12	24,405
April 21,	14,497	3,398	2,622	1.16	30.415
Total,	89,967	23,689	15,150	....	181.747
STEER 2:					
April 15,	11,931	3,008	2,427	.97	23.612
April 16,	12,049	3,012	1,993	1.26	25.112
April 17,	10,476	2,893	3,363	.91	30.603
April 18,	11,868	3,191	4,091	.81	33.137
April 19,	12,622	3,506	3,000	.65	19.500
April 20,	11,126	3,007	3,706	.63	23.348
April 21,	15,896	3,823	4,343	.58	25.189
Total,	85,968	22,440	22,923	....	180.501
STEER 3:					
April 15,	21,644	5,008	2,224	1.18	26.243
April 16,	18,448	4,011	2,734	1.25	34.175
April 17,	18.972	4,293	3,140	1.12	35.168
April 18,	18,588	4,097	2,699	1.09	29.419
April 19,	17,210	4,203	3,747	1.02	38.219
April 20,	14,623	3,805	3,370	1.10	37.070
April 21,	17,889	4,497	2,930	1.06	31.058
Total,	127,374	29,914	20,844	....	231.352

Composition of Feed and Feces.

	Cotton-seed feed. Per cent.	Feces.		
		Steer 1. Per cent.	Steer 2. Per cent.	Steer 3. Per cent.
Loss in air-drying,	7.36	....	....	....
Composition, air-dry:				
Water,	6.16	5.67	5.25	4.84
Ash,	2.75	3.86	6.24	3.69
Proteids,	9.09	10.19	11.28	9.50
Crude fiber,	35.13	43.83	43.08	42.34
Nitrogen free extract,	43.90	35.57	33.36	38.78
Ether extract,	2.97	0.88	0.79	0.85
	100.00	100.00	100.00	100.00
Total nitrogen,	1.455	1.630	1.805	1.520
Composition of dry matter:				
Ash,	2.93	4.09	6.59	3.88
Proteids,	9.69	10.80	11.90	9.98
Crude fiber,	37.44	46.47	45.47	44.49
Nitrogen free extract,	46.77	37.71	35.21	40.76
Ether extract,	3.17	0.93	0.83	0.89
	100.00	100.00	100.00	100.00
Total nitrogen,	1.551	1.728	1.905	1.597
Energy per gram of dry matter,	Cal. 4.566	Cal. 4.673	Cal. 4.589	Cal. 4.571

Per Day and Head.

	Fresh substance. Grms.	Dry matter. Grms.	Ash. Grms.	Organic matter. Grms.	Total N x 6.25. Grms.	Crude fiber. Grms.	Nitrogen-free extract. Grms.	Ether extract. Grms.	Energy. Cal.
STEER 1:									
Feed eaten,	6,351	5,521	163	5,358	535	2,067	2,581	175	25,209
Feces,	12,852	3,192	131	3,061	345	1,482	1,204	30	14,916
Digested,	....	2,329	32	2,297	190	585	1,377	145	10,293
Per cent. digested,	....	42.19	19.63	42.87	35.52	28.30	53.36	82.86	40.83
Nutritive ratio, 1:12.0.									
STEER 2:									
Feed eaten,	6,351	5,521	163	5,358	535	2,067	2,581	175	25,209
Feces,	12,281	3,038	200	2,838	362	1,381	1,070	25	13,941
Digested,	....	2,483	—37	2,520	173	686	1,511	150	11,268
Per cent. digested,	....	44.98	....	47.03	32.34	33.19	58.55	85.72	44.70
Nutritive ratio, 1:14.7.									
STEER 3:									
Feed eaten,	8,165	7,098	208	6,890	688	2,567	3,320	225	32,409
Feces,	18,196	4,066	158	3,908	406	1,809	1,657	36	18,586
Digested,	....	3,032	50	2,982	282	848	1,663	189	13,823
Per cent. digested,	....	42.72	24.04	43.28	40.98	31.92	50.09	84.00	42.66
Nutritive ratio, 1:14.1.									

The results on Steer 1 and Steer 3 agree quite closely, while in the case of Steer 2 the digestibility is about 2.5 per cent. higher than in the others, a result, as already noted, which was observed in most of these experiments.

PROTEID METABOLISM.

For the proteid metabolism, we have the following figures per day and head:

	Steer 1. Grms.		Steer 2. Grms.		Steer 3. Grms.	
Nitrogen in food,		85.63		85.63		110.09
Nitrogen in feces,	55.16		57.92		64.94	
Nitrogen in urine,	25.96		25.79		33.06	
Nitrogen in total excreta,		81.12		83.71		97.99
Gain,		4.51		1.92		12.10
Equivalent proteids,		28.19		12.00		75.63

The large apparent gain of nitrogen by Steer No. 3 certainly seems questionable and suggests possible error in either the collection or analyses of the urine, but the figures seem to be confirmed by those obtained for the mixed feces and urine.

ENERGY OF EXCRETA.

As in Experiment III, a uniform aliquot of the feces and urine was evaporated together, and a determination of nitrogen and of potential energy made in the air-dried material. The following are the results:

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Air-dry excreta:			
April 15,	4,386	3,214	5,215
April 16,	3,595	3,109	4,416
April 17,	3,400	3,285	4,402
April 18,	3,694	3,490	4,296
April 19,	3,420	3,806	4,411
April 20,	3,590	3,207	3,897
April 21,	3,704	4,028	4,703
Average,	3,684	3,448	4,477
	Per cent.	Per cent.	Per cent.
Nitrogen,	2.050	2.295	2.070
	Cal.	Cal.	Cal.
Energy per gram,	4.327	4.292	4.302

Assuming as before that the loss of nitrogen in air-drying is due to decomposition of urea, we have the following figures for the total energy of the excreta and for that of the urine.

Energy of Excreta.

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Total nitrogen of excreta,	81.12	83.71	97.99
Nitrogen of air-dried excreta,	75.52	79.13	92.67
Loss,	5.60	4.58	5.32
	Cal.	Cal.	Cal.
Energy of equivalent urea,	30	25	29
Energy of air-dried excreta,	15,941	14,799	19,260
Total energy of excreta,	15,971	14,824	19,289
Energy of feces,	14,916	13,941	18,586
Energy of urine,	1,055	883	703
Energy of urine per gram of nitrogen,	40.64	34.25	21.27

LIVE WEIGHTS.

This experiment covered only twenty-two days after the final change of feed with No. 1 and No. 2 and only thirty days for No. 3, a period too short to permit of an accurate estimate of the effect upon the weight of the animals. Moreover, as appears from Plates II, III and IV, the fluctuations of the live weights were such as to render any interpretation of them difficult. Apparently, however, Nos. 2 and 3 were nearly maintained, while No. 1 lost weight, but this loss took place shortly after a decrease in the feed and might not have continued had the experiment been prolonged. Accepting it as it stands, however, as represented by the broken line, we have the following:

Steer 1.

Weight, March 30th,	442 kgs.
Weight, April 16th,	430 kgs.
Loss in 17 days,	12 kgs.
Loss per day,	0.706 kgs.

Daily Weights.

Date.	Weight Before Watering.			Water Consumed.		
	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.	Steer 1. Kgs.	Steer 2. Kgs,	Steer 3. Kgs.
March 17, 1894,	420.0	440.6	404.6	14.5	0.0	0.0
March 18, 1894,	422.3	457.2	401.0	12.7	31.8	8.2
March 19, 1894,	436.3	446.8	425.9	27.2	0.0	39.9
March 20, 1894,	422.0	464.7	408.2	0.0	31.3	0.0
March 21, 1894,	430.9	447.7	425.5	24.7	0.0	35.8
March 22, 1894,	416.8	458.2	406.0	0.0	35.4	0.0
March 23, 1894,	445.4	451.3	423.0	41.3	8.2	36.8
March 24, 1894,	432.3	461.8	408.2	0.0	27.2	0.0
March 25, 1894,	424.3	451.6	414.1	5.9	0.0	18.6
March 26, 1894,	430.9	464.5	428.7	18.8	25.2	29.9
March 27, 1894,	440.0	466.3	425.0	20.4	15.4	17.2
March 28, 1894,	430.2	467.2	426.8	2.7	16.8	21.8
March 29, 1894,	441.3	466.8	420.9	22.0	14.1	12.7
March 30, 1894,	436.1	468.8	416.9	7.3	17.2	13.6
March 31, 1894,	444.1	465.6	422.8	21.1	16.1	26.3
April 1, 1894,	432.3	447.7	424.1	2.7	0.0	20.9
April 2, 1894,	442.2	455.4	428.7	19.1	19.5	22.7
April 3, 1894,	445.4	465.9	426.4	13.6	23.6	15.4
April 4, 1894,	446.8	465.0	430.0	12.7	12.2	20.9
April 5, 1894,	433.2	450.9	413.2	0.0	0.0	0.0
April 6, 1894,	435.4	453.6	419.6	17.3	15.4	22.7
April 7, 1894,	439.1	458.2	424.1	17.7	21.8	22.7
April 8, 1894,	440.0	466.3	429.6	15.4	22.7	22.7
April 9, 1894,	438.4	453.6	428.7	9.1	0.0	19.5
April 10, 1894,	425.0	446.8	410.5	0.0	6.8	1.4
April 11, 1894,	436.8	457.2	428.9	22.7	22.7	34.5
April 12, 1894,	439.1	465.9	424.1	13.2	20.4	13.4
April 13, 1894,	425.2	453.6	411.9	.9	1.4	4.1
April 14, 1894,	437.7	460.4	427.8	8.4	1.4	10.0
April 15, 1894,	426.4	465.9	426.8	0.0	16.3	20.4
April 16, 1894,	432.3	467.7	426.4	19.1	15.0	20.4
April 17, 1894,	425.9	453.6	427.3	3.2	0.0	20.4
April 18, 1894,	431.6	465.0	426.8	20.4	22.5	20.0
April 19, 1894,	422.7	465.9	416.9	6.6	16.1	7.3
April 20, 1894,	426.1	465.9	420.0	19.1	17.7	22.7
April 21, 1894,	430.5	465.0	424.1	21.1	20.0	22.3

Ten-day Averages.

Date.	Weight Before Watering.			Water Consumed.		
	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.	Steer 1. Kgs.	Steer 2. Kgs,	Steer 3. Kgs.
March 13-22, 1894,	422.6	448.7	409.0	11.41	16.70	17.37
March 14-23, 1894,	425.5	450.9	411.5	15.54	17.38	19.82
March 15-24, 1894,	427.2	451.9	411.4	14.72	16.36	16.83
March 16-25, 1894,	426.8	453.3	413.6	12.63	16.36	18.60
March 17-26, 1894,	428.1	454.4	414.5	14.51	15.91	16.87
March 18-27, 1894,	430.1	457.0	416.6	15.10	17.45	18.59
March 19-28, 1894,	430.9	458.0	419.1	14.10	15.95	19.95
March 20-29, 1894,	431.4	460.0	418.6	13.58	17.36	17.43
March 21-30, 1894,	432.8	460.4	419.5	14.31	15.95	18.59
March 22-31, 1894,	434.1	462.2	419.2	13.95	17.56	17.64
March 23-April 1, 1894,	435.7	461.2	421.1	14.22	14.02	19.73
March 24-April 2, 1894,	435.4	461.6	421.6	12.00	15.15	18.37
March 25-April 3, 1894,	436.7	462.0	423.4	13.36	14.79	19.91
March 26-April 4, 1894,	438.9	463.3	425.0	14.04	16.01	20.14
March 27-April 5, 1894,	439.2	462.0	423.5	12.16	13.49	17.15
March 28-April 6, 1894,	438.7	460.7	422.9	11.85	13.49	17.70
March 29-April 7, 1894,	439.6	459.8	422.7	13.35	13.99	17.79
March 30-April 8, 1894,	439.5	459.7	423.5	12.69	14.85	18.79
March 31-April 9, 1894,	439.7	458.2	424.7	12.87	13.13	19.38
April 1-10, 1894,	437.8	456.3	423.5	10.76	12.20	16.89
April 2-11, 1894,	438.2	457.3	424.0	12.76	14.47	18.25
April 3-12, 1894,	437.9	458.3	423.5	12.17	14.56	17.32
April 4-13, 1894,	435.9	457.1	422.1	10.90	12.34	16.19
April 5-14, 1894,	435.0	456.7	421.8	10.47	11.26	15.10
April 6-15, 1894,	434.3	458.2	423.2	10.47	12.89	17.14
April 7-16, 1894,	434.0	459.6	423.9	10.65	12.85	16.91
April 8-17, 1894,	432.7	459.1	424.2	9.20	10.67	16.68
April 9-18, 1894,	431.8	459.0	423.9	9.70	10.65	16.41
April 10-19, 1894,	430.3	460.2	422.7	9.45	12.26	15.19
April 11-20, 1894,	430.4	462.1	423.7	11.36	13.35	17.32
April 12-21, 1894,	429.8	462.9	423.2	11.20	13.08	16.09

The final results of the experiment per day and head, computed as before, are:

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Gain of nitrogen,	4.51	1.92	12.10
Equivalent "flesh,"	127.10	45.09	340.90
Loss of weight,	706.00	0.0	0.0
Computed loss of fat,	833.10	45.09	340.90

Estimated Production of Methan.

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Crude fiber digested,	585	686	848
Nitrogen-free extract digested,	1,377	1,511	1,663
Total,	1,962	2,197	2,511
Estimated methan,	89.3	100.0	114.2
	Cal.	Cal.	Cal.
Equivalent energy,	1,182	1,324	1,514

Energy Per Day and Head.

	Steer 1.		Steer 2.		Steer 3.	
	Ingesta. Cal.	Egesta. Cal.	Ingesta. Cal.	Egesta. Cal.	Ingesta. Cal.	Egesta. Cal.
Food,	25,209		25,209		32,409	
Loss from body:						
Fat (estimated),	7,903		428		3,233	
Excreta:						
Feces and urine,		15,971		14,824		19,289
Methan (estimated),		1,182		1,324		1,514
Gain by body:						
Proteids,		161		69		433
For maintenance,		15.798		9.420		14,406
	33,112	33,112	25,637	25,637	35,642	35,642

These results are fully as discordant and as little calculated to secure our confidence as those of the preceding periods.

On the whole, the results of the experiments of 1893-4 are decidedly unsatisfactory, owing to the apparently abnormal digestibility of the rations in the first two periods, and also to the very considerable and peculiar fluctuations in the live weight. Their chief value appears to be in showing that experiments of this sort are not so easy as might appear *a priori*, and that they require very close and constant supervision in order to secure satisfactory results.

Experiments of 1893–4.

Temperature of Stable.

1893-4.	Degrees. F.	1894.	Degrees. F.	1894.	Degrees. F.
December 12,	47	January 25,	43	March 10,	55
December 13,	44	January 26,	45	March 11,	58
December 14,	42	January 27,	45	March 12,	....
December 15,	44	January 28,	45	March 13,	57
December 16,	41	January 29,	48	March 14,	56
December 17,	44	January 30,	48	March 15,	51
December 18,	45	January 31,	44	March 16,	51
December 19,	44	February 1,	48	March 17,	57
December 20,	56	February 2,	46	March 18,	59
December 21,	56	February 3,	48	March 19,	61
December 22,	56	February 4,	51	March 20,	62
December 23,	56	February 5,	46	March 21,	59
December 24,	....	February 6,	45	March 22,	62
December 25,	....	February 7,	48	March 23,	64
December 26,	....	February 8,	49	March 24,	60
December 27,	....	February 9,	51	March 25,	....
December 28,	....	February 10,	51	March 26,	....
December 29,	....	February 11,	49	March 27,	44
December 30,	....	February 12,	50	March 28,	45
December 31,	....	February 13,	47	March 29,	47
January 1,	....	February 14,	47	March 30,	47
January 2,	50	February 15,	46	March 31,	52
January 3,	52	February 16,	42	April 1,	58
January 4,	....	February 17,	41	April 2,	56
January 5,	....	February 18,	47	April 3,	51
January 6,	58	February 19,	51	April 4,	52
January 7,	54	February 20,	51	April 5,	54
January 8,	51	February 21,	51	April 6,	54
January 9,	50	February 22,	48	April 7,	53
January 10,	49	February 23,	47	April 8,	50
January 11,	49	February 24,	46	April 9,	....
January 12,	47	February 25,	45	April 10,	....
January 13,	43	February 26,	49	April 11,	52
January 14,	48	February 27,	51	April 12,	52
January 15,	54	February 28,	49	April 13,	51
January 16,	53	March 1,	51	April 14,	53
January 17,	52	March 2,	53	April 15,	56
January 18,	49	March 3,	52	April 16,	56
January 19,	49	March 4,	55	April 17,	61
January 20,	50	March 5,	57	April 18,	64
January 21,	48	March 6,	60	April 19,	64
January 22,	51	March 7,	61	April 20,	65
January 23,	53	March 8,	58	April 21,	68
January 24,	54	March 9,	56		

EXPERIMENTS OF 1894—5.

Preliminary Feeding.

In view of the striking fluctuations in average live weight which occurred in the previous experiments, it seemed desirable to make some observations on the responsiveness of the animals to changes in feed, and to determine approximately the gross amount required for maintenance, before entering on the more elaborate experiments of the winter.

Accordingly, on July 22d, 1894, the same three animals, which had been on mountain pasture during the spring and up to the early part of July, were put upon a ration of 5.44 kgs. (12 lbs.) of the same cut timothy hay which was used in Experiments III and IV.

This feeding was continued until Aug. 16th, inclusive. Beginning August 17th, long hay of the crop of 1894, consisting chiefly of timothy (*Phleum pratense*) with some admixture of blue grass (*Poa pratensis*) was fed, the quantity remaining the same. August 21st, this was replaced by the same amount of the cut hay prepared as described later (p. 75). This hay was of the same quality as the long hay used for the four preceding days except that it was free from the admixture of blue grass. This feeding was continued until Sept. 20 for Nos. 1 and 2 and until Sept. 24th for No. 3.

The hay was given in two feeds, at night and in the morning, and the animals were weighed early in the morning before feeding or watering. Rock salt was kept in the mangers and a little fine salt given in addition, at first every two or three days, and after Aug. 14th daily. On Sept. 13th, it was noticed that Steer No. 3 was eating the sawdust used as bedding, and a strip of cocoa matting was fastened under the fore feet of each animal.

The daily weights and the ten-day averages of animals and water are contained in the following tables, and are also recorded graphically in Plates V,VI and VII, in which, as in the previous plates, the light black line represents the daily results and the heavier red line the ten-day averages.

Daily Weights.

Date.	Steer 1.		Steer 2.		Steer 3.	
	Weight. Kgs.	Water. Kgs.	Weight. Kgs.	Water. Kgs.	Weight. Kgs,	Water. Kgs.
July 22,	461.3	0.0	509.2	0.0	429.6	0.0
July 23,	453.6	3.6	495.3	0.0	434.1	28.6
July 24,	469.5	19.1	485.8	0.0	421.8	0.0
July 25,	454.5	0.0	487.6	17.7	429.6	24.9
July 26,	450.9	15.0	489.9	21.3	433.2	24.0
July 27,	451.8	23.1	474.0	0.0	413.2	0.0
July 28,	452.2	22.2	480.8	27.2	420.5	26.8
July 29,	460.4	28.6	488.5	27.2	427.3	26.3
July 30,	453.6	12.2	472.2	0.0	412.8	5.9
July 31,	458.1	26.3	477.7	23.1	424.1	27.2
August 1,	458.1	24.5	485.4	25.9	431.4	27.2
August 2,	453.6	12.7	488.5	18.1	417.3	2.7
August 3,	458.1	24.9	480.4	10.4	428.2	27.2
August 4,	464.0	24.9	489.9	23.1	436.8	27.7
August 5,	452.7	5.4	475.8	0.0	424.1	4.1
August 6,	463.6	23.1	485.8	27.7	438.6	27.7
August 7,	459.0	15.0	494.0	26.8	431.4	15.9
August 8,	464.9	26.3	489.4	25.4	435.9	24.5
August 9.	458.6	13.6	490.4	20.9	415.9	0.0
August 10,	465.4	27.2	476.3	2.7	425.5	26.3
August 11,	455.9	7.7	485.8	27.2	425.9	19.1
August 12,	464.9	27.2	490.4	22.2	430.9	23.1
August 13,	458.1	9.1	499.0	24.5	425.9	12.2
August 14,	469.5	27.2	483.6	4.5	436.8	27.7
August 15,	458.6	10.4	489.5	18.1	421.4	0.9
August 16,	464.9	26.8	495.8	23.1	433.2	27.7
August 17,	453.6	4.5	496.7	18.6	425.0	7.7
August 18,	460.9	27.2	492.6	20.4	433.2	26.3
August 19,	463.6	26.8	494.4	22.2	435.4	22.7
August 20,	462.7	21.8	494.9	26.3	426.8	10.9
August 21,	453.6	11.3	489.4	13.2	431.8	24.5
August 22,	463.6	27.2	496.2	23.1	413.2	1.4
August 23,	453.6	8.2	490.8	14.1	417.7	26.8
August 24,	459.0	27.7	488.1	18.1	424.6	26.8
August 25,	453.6	16.8	479.5	10.9	411.9	5.0
August 26,	459.0	27.7	490.8	23.6	422.3	28.6
August 27,	453.6	13.6	492.6	21.8	432.3	26.8
August 28,	459.9	27.7	483.1	7.3	413.2	0.0
August 29,	457.2	18.1	488.1	22.7	422.3	26.8
August 30,	455.9	19.1	489.0	20.9	409.6	6.4
August 31,	456.3	22.7	494.4	23.6	420.5	28.1
September 1,	453.6	15.9	478.6	2.3	415.6	13.6
September 2,	458.6	26.3	487.6	24.9	423.2	25.4
September 3,	462.2	26.8	492.6	22.7	427.3	24.9
September 4,	453.6	10.9	489.0	19.1	413.2	5.9
September 5,	458.1	27.2	484.5	18.2	425.0	29.0

Daily Weights—Continued.

Date.	Steer 1.		Steer 2.		Steer 3.	
	Weight. Kgs.	Water. Kgs.	Weight. Kgs.	Water. Kgs.	Weight. Kgs,	Water. Kgs.
September 6,	444.5	9.1	486.8	21.8	413.2	5.9
September 7,	453.6	24.9	488.5	21.8	424.1	26.8
September 8,	458.1	27.2	494.9	24.9	416.4	10.9
September 9,	452.2	17.2	480.8	8.2	426.8	28.1
September 10,	458.1	24.0	493.5	24.5	426.4	15.9
September 11,	461.8	24.9	479.0	5.4	433.6	25.9
September 12,	445.4	5.4	486.3	24.5	415.0	1.8
September 13,	457.7	31.8	480.8	10.4	426.4	27.2
September 14,	446.8	12.7	486.7	22.7	420.5	13.2
September 15,	455.9	24.9	488.1	21.8	428.6	27.2
September 16,	447.7	10.0	472.2	4.1	411.0	5.4
September 17,	453.1	24.0	484.0	26.8	420.9	26.8
September 18,	430.9	0.0	487.6	20.9	437.7	30.8
September 19,	442.2	29.5	471.3	0.0	417.7	0.0
September 20,	434.1	11.3	485.4	27.7	412.7	10.4
September 21,	440.0	24.0	470.4	2.3	418.2	20.4
September 22,	432.3	9.1	471.7	15.4	400.5	0.0
September 23,	446.8	25.9	458.1	5.0	410.5	25.9
September 24,	437.2	11.3	473.1	27.2	418.2	24.9
September 25,	440.9	22.7	478.5	22.2	401.9	0.0
September 26,	430.9	10.0	464.9	2.3	420.5	22.2
September 27,	436.3	27.2	469.9	22.7	401.9	0.0
September 28,	433.2	15.9	465.8	12.7	415.0	25.9
September 29,	442.2	24.9	476.3	19.5	408.2	6.8
September 30,	413.7	0.0	468.1	0.0	418.2	0.0
October 1,	428.7	18.6	478.5	28.6	412.8	26.3
October 2,	434.1	27.2	483.6	24.9	420.4	24.9
October 3,	438.2	16.3	465.8	0.0	416.8	28.6
October 4,	430.5	27.7	476.3	29.9	425.0	17.7
October 5,	439.0	27.7	486.7	26.8	427.7	27.2
October 6,	444.0	23.6	485.4	18.1	429.1	20.9
October 7,	435.4	17.2	487.6	23.1	425.9	26.8
October 8,	435.9	20.4	467.2	0.0	428.2	27.7
October 9,	441.3	26.8	474.5	27.2	427.3	25.4
October 10,	436.3	15.0	479.5	26.8	425.9	24.0
October 11,	439.9	21.8	487.2	26.3	425.0	27.7
October 12,	442.7	22.7	479.0	27.7	424.1	26.3
October 13,	448.6	25.4	491.7	33.6	430.9	27.2
October 14,	437.7	9.5	476.3	27.7	413.7	3.6
October 15,	446.8	27.2	483.6	31.7	422.3	26.3
October 16,	440.0	12.2	489.5	26.8	429.6	26.8
October 17,	445.0	27.2	490.8	28.6	430.9	25.4
October 18,	453.6	27.2	493.1	24.0	435.9	27.7
October 19,	447.7	20.4	496.7	27.2	441.4	29.0
October 20,	437.7	10.4	478.6	2.7	424.1	1.8
October 21,	445.9	29.5	489.5	30.4	431.8	27.2
October 22,	455.9	28.1	496.7	26.3	435.9	26.3
October 23,	448.6	18.1	482.7	4.5	441.4	27.7
October 24,	456.8	23.1	499.0	30.4	445.9	23.6
October 25,	458.2	26.3	496.7	17.7	446.8	25.9
October 26,	456.8	22.7	499.4	22.7	429.6	3.6
October 27,	440.4	2.7	482.2	2.7	438.6	28.1
October 28,	451.3	26.8	492.2	28.1	444.5	27.2
October 29,	453.6	18.1	499.0	24.9	426.4	2.3
October 30,	458.2	27.2	501.2	22.7	435.9	27.2
October 31,	450.9	18.6	490.4	12.2	442.3	26.8
November 1,	459.0	27.7	499.0	27.7	452.3	27.7
November 2,	450.4	14.1	507.6	27.7	453.6	27.7
November 3,	455.2	27.2	510.3	27.2	441.3	12.2
November 4,	454.5	15.0	512.6	24.9	446.8	28.1
November 5,	463.6	25.4	516.2	27.2	450.4	24.9
November 6,	450.4	10.4	508.1	17.2	448.6	19.1
November 7,	458.2	20.9	509.4	17.7	448.2	20.0
November 8,	450.4	11.8	497.6	6.8	438.6	9.1
November 9,	451.3	16.8	499.0	20.4	440.9	15.4
November 10,	453.6	20.4	491.7	15.9	444.1	23.1
November 11,	448.2	13.6	489.0	15.0	441.3	14.1
November 12,	452.3	22.7	490.4	20.0	450.0	27.2
November 13,	455.9	18.6	495.8	19.1	440.9	11.3
November 14,	448.2	11.8	496.7	15.4	439.1	14.5
November 15,	445.9	16.3	488.5	12.7	439.1	23.1
November 16,	446.8	21.3	483.6	18.6	428.7	10.9
November 17,	440.4	12.2	495.3	5.0	434.5	24.5
November 18,	448.2	24.5	481.7	5.0	435.4	22.7
November 19,	443.6	13.6	489.9	23.6	435.9	19.1
November 20,	443.6	15.0	485.8	11.8	430.9	13.6
November 21,	440.9	14.5	484.5	16.8	433.6	21.8
November 22,	445.0	23.1	488.1	20.0	431.8	18.1
November 23,	445.0	16.8	484.9	13.2	430.9	16.3
November 24,	440.9	11.8	490.4	20.4	432.7	17.7
November 25,	440.0	17.2	479.0	5.4	431.4	14.5
November 26,	440.9	16.3	489.5	24.5	430.5	16.8
November 27,	443.6	18.1	485.8	12.7	431.4	21.8
	....	13.2	....	20.4	....	19.1

Ten-day Averages.

Date.	Steer 1.		Steer 2.		Steer 3.	
	Weight. Kgs.	Water. Kgs.	Weight. Kgs.	Water. Kgs.	Weight. Kgs,	Water. Kgs.
July 22-31,	456.6	....	486.1	....	424.6	....
July 23-August 1,	456.3	17.46	483.7	14.74	424.8	19.09
July 24-August 2,	456.3	18.37	483.0	16.55	423.1	16.50
July 25-August 3,	455.1	18.95	482.5	17.59	423.8	19.22
July 26-August 4,	456.1	21.44	483.7	18.13	424.5	19.50
July 27-August 5,	456.3	20.48	481.3	16.00	423.6	17.51
July 28-August 6,	457.4	20.93	482.5	18.77	426.1	20.28
July 29-August 7,	458.1	20.26	483.8	18.73	427.2	19.19
July 30-August 8,	458.6	20.03	483.9	18.55	428.1	19.01
July 31-August 9,	459.1	20.17	485.7	20.64	428.4	18.42
August 1-10,	459.8	20.26	485.6	18.10	428.5	18.33
August 2-11,	459.6	18.58	485.6	18.23	428.0	17.52
August 3-12,	460.7	20.03	485.8	18.64	429.3	19.56
August 4-13,	460.7	18.45	487.7	20.05	429.1	18.06
August 5-14,	461.3	18.68	487.1	18.19	429.1	18.06
August 6-15,	461.9	19.13	488.4	20.00	428.8	17.74
August 7-16,	462.0	19.05	489.4	19.54	428.3	17.74
August 8-17,	461.4	18.00	489.7	18.72	427.6	16.92
August 9-18,	461.0	18.09	490.0	18.22	427.4	17.10
August 10-19,	461.5	19.41	490.4	18.35	429.3	19.37
August 11-20,	461.3	18.87	492.3	20.71	429.5	17.83
August 12-21,	461.0	19.23	492.6	19.31	430.0	18.37
August 13-22,	460.9	19.23	493.2	19.40	428.3	16.20
August 14-23,	460.5	19.14	492.4	18.26	427.5	17.66
August 15-24,	459.4	19.19	492.8	19.72	426.2	17.57
August 16-25,	458.9	19.83	491.8	19.00	425.3	17.98
August 17-26,	458.3	19.92	491.3	19.05	424.2	18.07
August 18-27,	458.3	20.83	490.9	19.37	424.9	19.98
August 19-28,	458.2	20.88	490.0	18.06	422.9	17.85
August 20-29,	457.6	20.01	489.4	18.11	421.6	17.76
August 21-30,	456.9	19.74	488.8	17.57	419.9	17.31
August 22-31,	457.2	20.88	489.3	18.61	418.8	17.67
August 23-September 1,	456.2	19.75	487.5	16.53	419.0	18.89
August 24-September 2,	456.7	21.56	487.2	17.61	419.6	18.75
August 25-September 3,	457.0	21.47	487.6	18.07	419.8	18.56
August 26-September 4,	457.0	20.88	488.6	18.89	420.0	18.65
August 27-September 5,	456.9	20.83	488.0	17.85	420.2	18.69
August 28-September 6,	456.0	20.38	487.3	17.85	418.3	16.60
August 29-September 7,	455.4	20.10	487.9	19.30	419.4	19.28
August 30-September 8,	455.5	21.01	488.5	19.52	418.8	17.69
August 31-September 9,	455.1	20.82	487.7	18.25	420.5	19.86
September 1-10,	455.8	20.95	487.6	18.34	421.1	18.64
September 2-11,	456.1	21.85	487.7	18.65	422.9	19.87
September 3-12,	454.8	19.76	487.5	18.61	422.1	17.51
September 4-13,	454.3	20.26	486.4	17.38	422.0	17.74
September 5-14,	453.6	20.44	486.1	17.74	422.7	18.47
September 6-15,	453.4	20.21	486.5	18.60	423.1	18.29
September 7-16,	453.7	20.30	485.1	16.88	422.9	18.24
September 8-17,	453.7	20.21	484.6	17.23	422.6	18.24
September 9-18,	451.0	17.49	483.9	16.93	424.7	20.23
September 10-19,	450.0	18.72	483.0	16.11	423.8	17.42
September 11-20,	447.6	17.45	482.1	16.43	422.4	16.87
September 12-21,	445.4	17.36	481.3	16.12	420.9	16.32
September 13-22,	444.1	17.78	479.8	15.21	419.4	16.14
September 14-23,	443.0	17.14	477.6	14.67	417.8	16.01
September 15-24,	442.0	17.00	476.2	15.12	417.6	17.18
September 16-25,	440.5	16.78	475.2	15.16	414.9	14.46
September 17-26,	438.8	16.78	474.5	14.98	415.9	16.14
September 18-27,	437.2	17.10	473.1	14.57	414.0	13.46
September 19-28,	437.4	18.69	470.9	13.75	411.7	12.97
September 20-29,	437.4	18.23	471.4	15.70	410.8	13.65
September 21-30,	435.8	19.27	469.7	15.34	410.9	14.27
September 22-October 1,	434.7	18.73	470.5	17.97	410.3	14.86
September 23-October 2,	434.9	20.54	471.7	18.92	412.3	17.35
September 24-October 3,	434.4	19.58	472.5	18.42	412.9	17.62
September 25-October 4,	433.3	21.22	472.8	18.69	413.6	16.90
September 26-October 5,	433.1	21.72	473.6	19.15	416.2	19.62
September 27-October 6,	434.4	23.06	475.6	20.73	417.1	19.49
September 28-October 7,	434.4	22.06	477.4	20.77	419.5	22.17
September 29-October 8,	434.6	22.53	477.6	19.50	420.8	22.35
September 30-October 9,	434.5	22.72	477.4	20.27	422.7	24.21
October 1-10,	436.3	23.05	478.5	20.54	423.9	24.95
October 2-11,	437.5	22.37	479.4	20.31	425.1	25.09
October 3-12,	438.3	21.92	478.9	20.59	425.5	25.23
October 4-13,	439.4	22.83	481.5	23.95	426.9	25.09
October 5-14,	440.1	21.01	481.5	23.73	425.8	23.68
October 6-15,	440.9	20.96	481.2	24.22	425.2	23.59
October 7-16,	440.5	19.82	481.6	25.09	425.3	24.18
October 8-17,	441.4	20.82	481.9	25.64	425.8	24.04
October 9-18,	443.2	21.50	484.5	23.04	426.6	24.04
October 10-19,	443.8	20.86	486.7	23.04	428.0	24.40
October 11-20,	444.0	20.40	486.7	25.63	427.8	22.18
October 12-21,	444.6	21.17	486.9	26.04	428.5	22.13
October 13-22,	455.9	21.71	488.7	25.90	429.7	23.13

Ten-day Averages—Continued.

Date.	Steer 1.		Steer 2.		Steer 3.	
	Weight. Kgs.	Water. Kgs.	Weight. Kgs.	Water. Kgs.	Weight. Kgs.	Water. Kgs.
October 14-23,	445.9	20.98	487.8	22.99	430.7	22.18
October 15-24,	447.8	22.34	490.0	23.26	433.9	24.18
October 16-25,	448.9	22.25	491.3	21.86	436.4	24.14
October 17-26,	450.6	23.30	492.3	21.45	426.4	21.82
October 18-27,	450.2	20.86	491.5	18.86	437.1	22.09
October 19-28,	449.9	20.81	491.4	19.27	438.0	22.04
October 20-29,	450.5	20.58	491.6	19.04	436.5	19.37
October 21-30,	452.6	22.26	493.9	21.04	437.7	21.91
October 22-31,	453.1	21.17	494.0	19.22	438.7	21.87
October 23-November 1,	453.4	21.13	494.2	19.36	440.4	22.01
October 24-November 2,	453.6	20.73	496.7	21.68	441.6	22.01
October 25-November 3,	453.7	21.14	497.8	21.36	441.1	20.87
October 26-November 4,	453.3	20.01	499.4	22.08	441.1	21.09
October 27-November 5,	454.0	20.28	501.1	22.53	443.2	23.22
October 28-November 6,	455.0	21.05	503.7	23.98	444.2	22.32
October 29-November 7,	455.7	20.46	505.4	22.94	444.6	21.60
October 30-November 8,	455.4	19.83	505.2	21.13	445.8	22.28
October 31-November 9,	454.7	18.79	506.0	20.90	446.3	21.10
November 1-10,	455.0	18.97	505.2	21.27	446.5	20.73
November 2-11,	453.9	17.56	504.2	20.00	445.4	19.37
November 3-12,	454.1	18.42	502.4	19.23	445.0	19.32
November 4-13,	453.9	17.56	501.0	18.42	445.0	19.23
November 5-14,	453.2	17.24	499.4	17.47	444.2	17.87
November 6-15,	451.4	16.33	496.6	16.02	443.1	17.69
November 7-16,	451.1	17.42	494.2	16.16	441.1	16.87
November 8-17,	449.3	16.55	492.8	14.89	439.7	17.32
November 9-18,	449.1	17.82	491.3	14.71	439.4	18.68
November 10-19,	448.3	17.50	490.3	15.03	438.9	19.06
November 11-20,	447.3	16.96	489.7	14.62	437.6	18.10
November 12-21,	446.6	17.06	489.2	14.80	436.8	18.87
November 13-22,	445.9	17.09	489.0	14.80	435.0	17.96
November 14-23,	444.8	16.91	487.9	14.21	434.0	18.46
November 15-24,	444.0	16.91	487.3	14.71	433.4	18.78
November 16-25,	443.4	17.00	486.3	13.98	432.6	17.92
November 17-26,	442.9	16.50	486.9	14.57	432.8	18.51
November 18-27,	443.2	17.09	486.0	15.34	432.5	18.24
November 19-28,	442.5	15.96	487.1	16.88	431.9	17.83
November 20-29,	442.2	15.96	486.3	15.01	430.6	17.47
November 21-30,	441.8	16.37	487.1	16.65	430.5	18.92
November 22-December 1,	441.2	16.10	487.7	16.56	429.6	18.24
November 23-December 2,	441.1	16.60	487.5	16.06	429.4	19.15
November 24-December 3,	439.3	15.01	488.2	16.42	427.7	17.62
November 25-December 4,	439.1	16.69	487.2	15.06	427.0	18.06

During the early portion of the feeding, the ration appeared to be sufficient, but later, especially after the change to the new hay, a loss of weight took place which toward the last became very marked, the rather sudden falling off reminding one of the similar phenomenon in Experiments I and III. On Sept. 21st, the ration of Nos. 1 and 2 was increased to 6.35 kgs. (14 lbs.) and on Sept. 25 the same increase was made in the ration of No. 3. On Sept. 29th, the ration of all three animals was changed to

Mixed timothy and red clover hay,*	6.35 kgs.
Wheat bran,	.91 kgs.
Gluten feed,	.91 kgs.

in order to improve the condition of the animals. This ration was continued until Nov. 4th. During the next four days the grain was withdrawn at the rate of 4.45 kgs. (1 lb.) per day, and the ration, from Nov. 8th on, consisted of 6.35 kgs. of mixed hay. The grain ration caused a rather rapid gain, amounting in 35 days to about 23 kgs. by

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*Fed long.

Steer 1 and about 36 kgs. by Steers 2 and 3, equal to 0.65 kgs. and 1.04 kgs. (1.4 lbs. and 2.3 lbs.) per day respectively, on a relatively light ration. When the grain was withdrawn an almost equally rapid decrease in live weight took place, more marked in the case of Steer 2 than of the others, lasting for from 15 to 30 days. After this, substantially the same ration, as will appear later, produced a slight but steady gain.

These results illustrate anew the utterly fallacious character of conclusions based upon a few weighings or upon changes of weight shortly following radical changes of feed. A ration of four pounds of grain per day, with a limited amount of hay, is clearly insufficient to produce a real gain of tissue of over 2 lbs. per day, and it is equally certain that even if the animals had been partially fattened they would not suffer any such loss of tissue upon a maintenance ration as would be indicated by the decrease in live weight. The only possible conclusion is that this gain and subsequent loss were largely due to changes in the amount of "ballast" contained in the alimentary canal and perhaps to variations in the percentage of water in the blood and solid tissues.

With a view to ascertaining how far such variations in live weight could be accounted for by variations in the excretion of feces and urine, it was decided to undertake a continuous daily record of the income and outgo of the animals, with the exception of the respiratory products, for whose determination the Station has no facilities.

At the same time, it was the intention to vary the ration as should prove necessary until a maintenance ration was reached. The 6.35 kgs. of hay, however, proved to be so nearly a maintenance ration that no changes were made in it, the fluctuations of live weight were comparatively small, and but little information was secured as to their causes. Incidentally, however, data of some interest were secured regarding the digestibility of the ration and the technique of digestion experiments.

Later, a second experiment was added, in which part of the hay was replaced by starch.

Experiment VI.

November 28, 1894 to March 13, 1895.----106 Days.

Previous to the experiment the animals were dehorned (on November 6th). They were placed in the special stalls described below on November 23d, 1894, and the collection, weighing and sampling of the excreta began on Nov. 28th. At this time they were receiving the same feed as had been given since November 8th, namely, 6.35 kgs. mixed timothy and clover hay. On Nov. 27th a sample of this hay was taken for determination of moisture and nitrogen.

After November 28th the daily ration of hay was moistened with one kilogram of water.

Beginning December 13th, 1894, cut timothy hay was substituted for the mixed hay, the same weight being given, namely, 6.35 kgs. This ration was continued without change to March 13th, 1895, inclusive.

As noted, the collection of excreta began November 28th, and continued uninterrupted, except by occasional accidents to the apparatus with one or the other animal, until February 15th, 1895, inclusive. At that time it was found that the animals had become sore on the rump from friction of the apparatus. They were therefore removed to ordinary stalls, the same feeding being continued. On March 6th, the sores having healed and the apparatus having been readjusted, the animals were returned to their original stalls and the collection of the excreta resumed.

APPLIANCES.

It being desired to keep a continuous record of the daily excretion of feces and urine for a considerable time, an attempt was made to devise a form of apparatus which should render this work as easy as possible. For the collection of the urine the well-known urine funnel was used. For the feces it was at first attempted to apply the method used for Wolff* for digestion experiments on the horse, namely, a rubber sheet attached to the animal and suspended in an inclined position. This failing to give satisfactory results, Mr. Hess devised the form now in use, which, at least with animals on dry feed, renders experimenting with steers as simple as with sheep.

It consists in brief of a funnel-shaped rubber tube, about 25 cm. in diameter at the bottom, fitted around the hind quarters and held in place by a light harness. The tube passes through a hole in the raised floor and the lower end is held open by an iron ring sewed into it, which also serves as a weight. The feces drop through the tube and are caught in a galvanized iron box. The apparatus has been found to work very satisfactorily, very few breakages or losses having occurred.

The stall is substantially what is known as the Bidwell stall, the animals not being tied but kept in place by a rope stretched across the rear end of the stall. The manger was made deeper than in the ordinary Bidwell stall and, by means of an adjustable grating in front, the length of the stall could be varied to suit the animal. They could readily lie down but could not turn around. In place of bedding, two thicknesses of ordinary cocoa matting were nailed to the floor. When the animals were weighed the urine funnel was removed and the remainder of the apparatus caught up and weighed with the animal.

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*Landw. Vers. Stat. 21, 19.

METHODS.

Daily Routine.—The experimental day ended with the daily weighing of the animals at 1 p. m. The animals were watered while standing on the scales and then re-weighed. The difference, with the addition of one kilogram for the water used to moisten the hay, gave the amount of water consumed. The ration was given in two approximately equal feeds, morning and evening. As just stated the live weight was taken at 1 p. m., and this weighing, as in previous experiments, was considered as the last act of the experimental day, so that each day's consumption of water was recorded as of the same date with the next succeeding weight of the animal. At the time of the daily weighing, the urine funnel was rinsed out with 200 cc. of distilled water and the receptacles for the excreta were replaced with clean ones. Rock salt was kept in the mangers of the animals at all times.

Weighing and Sampling of Feed and Excreta.—In all cases special care was taken to get truly representative samples.

In the case of the hay the object of the experiment required that it should be of as nearly uniform quality as possible for a considerable period. In order to ensure this, on August 20, 1894, about 3,000 kilograms of nearly clear timothy, containing a very little clover, grown upon the Station Farm in 1894, were run through a feed cutter, cutting to a length of 7.5 to 10 cm. The cut hay was shoveled over twice on the clean barn floor and then spread out evenly. A narrow ditch was then dug through the mass diagonally, the hay removed down to the floor, mixed on a clean floor and sub-sampled by taking out three different portions down to the floor and mixing them. The weight of this sub-sample was about 40 kilograms. A second ditch was then dug along the other diagonal of the mass of cut hay, and the hay removed and sub-sampled in the same way as before, the weight of the sub-sample being substantially the same. The hay was then carried in bags to the loft in the Experiment Barn and spread on a tight floor, it being distributed as much as possible as the bags were emptied. The two sub-samples were each separately spread on a concrete floor, mixed, and sub-sampled again by taking from 15 different points a total amount of about 5½ kgs. in each case, going down to the floor each time. Each of these samples was chopped in a rotary meat chopper and 4,965 grammes of each, after mixing, taken to the laboratory. At the laboratory each sample was thoroughly air-dried, coarsely ground while still warm, mixed and sub-sampled again, and this final sub-sample ground fine and preserved for analysis.

The composition of the dry matter of these two samples on the average of two closely concordant determinations was as follows:

Percentage Composition.

	A.	B.	Average.
Ash,	6.53	6.52	6.53
Proteids,	8.15	8.15	8.15
Non-proteids,	0.51	0.38	0.44
Crude fiber,	34.37	34.41	34.39
Nitrogen-free extract,	47.78	47.82	47.80
Ether extract,	2.66	2.72	2.69
	100.00	100.00	100.00
Heat of combustion per gram,	4.426 Cal.	....	....

The close agreement in the composition of these two samples appears to show very correct sampling. The animals were fed from this hay from Aug. 21 to Sept. 28, 1894, inclusive, as already described, no sample being taken during that time. The use of the hay was then suspended for a time. Beginning Dec. 13th, 1894, the use of the hay was resumed. It was weighed out in cloth bags for seven days in advance and at the time of weighing it a small portion was taken from each bag, the mixed portions serving as a sample for determination of dry matter and also for the determination of nitrogen as a further check upon the accuracy of the sample. The percentages of nitrogen found varied more or less, but in all cases were notably higher than were found in the samples taken in August. The results of these analyses of weekly samples were as follows:

When Fed.	Loss in air-drying. Per cent.	In Air-dry Matter.		Water in hay as sampled. Per cent.	Nitrogen in dry matter. Per cent.
		Moisture. Per cent.	Nitrogen. Per cent.		
Before December 13, 1894,*	7.80	4.49	1.680	11.94	1.768
December 13-19,	9.30	3.94	1.485	12.88	1.546
December 20-26,	7.00	4.03	1.410	10.75	1,469
December 27-January 2, 1895,	5.50	4.67	1.380	9.92	1.448
January 3-9,	7.30	4.27	1.455	11.26	1.520
January 10-16,	7.30	5.95	1.405	12.82	1.494
January 17-23,	14.10	3.99	1.470	17.53	1,531
January 24-30,	10.10	3.12	1.475	12.91	1.523
January 31-February 6,	7.70	4.34	1.365	11.71	1.427
February 7-13,	8.20	3.97	1.525	11.85	1.588
February 14-20,	9.30	4.48	1.545	13.36	1.617
February 21-27,	8.90	....	1.455	....	....
February 28-March 6,	11.90	....	1.475	....	....
March 7-13,	13.60	....	1.445	....	....
March 21-27,	9.80	....	1.405	....	....

The writer is unable to explain the discrepancy between these results and those upon the two samples taken in August. The analyses were in every case the mean of two closely accordant determinations, and a repetition in several cases confirmed the correctness of the results. The only difference in the samples lies in the fact that, as noted, a portion of the hay was used during August and September, so that these later samples represented but a portion of the whole lot. In view, however, of the very careful way in which the hay was mixed, it seems hardly possible that this fact can explain the difference observed.

---

*Mixed hay.

The total amount of feces excreted was weighed at the close of the experimental day and sampled by emptying it upon a clean concrete floor, mixing as thoroughly as possible with a shovel and taking a number of portions from different parts of the mass. A test of this method of sampling, the details of which will be given later, showed it to be accurate.

The urine, with the addition of 200 cc. of distilled water used to rinse out the urine funnel, was weighed at the close of the experimental day, thoroughly mixed, and a sample taken for analysis.

Analytical Methods.—A preliminary air-drying of the samples of hay and feces was conducted in a drying closet heated by steam, the temperature of which ranged from 50 to 60 degrees C. As already stated (p. 26), no material loss of nitrogen is to be feared under these conditions from the feces of hay-fed cattle. The remaining determinations were made by the methods of the Association of Official Agricultural Chemists. The nitrogen of the urine was determined by the Kjeldahl method, and the determinations of energy were made with the bomb calorimeter.

DAILY RECORDS AND AVERAGES.

In order to avoid cumbering the text with a mass of figures, the detailed daily results have been tabulated in the appendix, and only summaries of them are given in connection with the discussion. The analytical results there recorded are, in most cases, the results of single determinations, but in the analyses of food, and also of feces from the special digestion trial, the results are the mean of two accordant determinations.

TEMPERATURE OF STABLE.

The temperature of the stable was recorded continuously by a Draper metallic thermometer hung about on a level with the backs of the animals. The thermometer had been previously compared with an accurate mercurial thermometer and found to be correct.

The following table shows the average daily temperature for the 24 hours ending at noon on the day named. Inasmuch as an error of a fraction of a degree would be of no significance, these averages have been estimated as nearly as possible by the eye from the record on the thermometer dial in place of using a planimeter.

Stable Temperatures----Degrees F.

1894.	
July 24,	75
July 25,	75
July 26,	..
July 27,	..
July 28,	..
July 29,	80
July 30,	78
July 31,	79
August 1,	79
August 2,	78
August 3,	78
August 4,	78
August 5,	71
August 6,	72
August 7,	77
August 8,	78
August 9,	78
August 10,	..
August 11,	73
August 12,	72
August 13,	71
August 14,	75
August 15,	80
August 16,	75
August 17,	71
August 18,	71
August 19,	77
August 20,	74
August 21,	73
August 22,	70
August 23,	72
August 24,	..
August 25,	71
August 26,	71
August 27,	68
August 28,	68
August 29,	68
August 30,	69
August 31,	65
September 1,	63
September 2,	64
September 3,	69
September 4,	70
September 5,	69
September 6,	71
September 7,	69
September 8,	68
September 9,	68
September 10,	70
September 11,	65
September 12,	60
September 13,	61
September 14,	62
September 15,	67
September 16,	70
September 17,	70
September 18,	67
September 19,	65
September 20,	61
September 21,	60
September 22,	63
September 23,	62
September 24,	65
September 25,	59
September 26,	55
September 27,	52
September 28,	57
September 29,	60
September 30,	61
October 1,	62
October 2,	55
October 3,	60
October 4,	58
October 5,	54
October 6,	51
October 7,	56
October 8,	61
October 9,	60
October 10,	58
October 11,	58
October 12,	54
October 13,	58
October 14,	56
October 15,	51
October 16,	52
October 17,	61
October 18,	60
October 19,	59
October 20,	62
October 21,	65
October 22,	63
October 23,	61
October 24,	60
October 25,	59
October 26,	57
October 27,	58
October 28,	57
October 29,	57
October 30,	60
October 31,	58
November 1,	56
November 2,	57
November 3,	61
November 4,	53
November 5,	55
November 6,	52
November 7,	50
November 8,	50
November 9,	51
November 10,	50
November 11,	..
November 12,	48
November 13,	49
November 14,	52
November 15,	50
November 16,	54
November 17,	58
November 18,	52
November 19,	52
November 20,	48
November 21,	48
November 22,	52
November 23,	54
November 24,	55
November 25,	50
November 26,	50
November 27,	53
November 28,	53
November 29,	49
November 30,	50
December 1,	51
December 2,	52
December 3,	52
December 4,	51
December 5,	49
December 6,	50
December 7,	51
December 8,	51
December 9,	53
December 10,	53
December 11,	52
December 12,	53
December 13,	50
December 14,	49
December 15,	51
December 16,	55
December 17,	55
December 18,	53
December 19,	53
December 20,	53
December 21,	54
December 22,	54
December 23,	52
December 24,	51
December 25,	50
December 26,	51
December 27,	49
December 28,	46
December 29,	41
December 30,	42
December 31,	47
1895.	
January 1,	47
January 2,	45
January 3,	47
January 4,	48
January 5,	46
January 6,	47
January 7,	52
January 8,	56
January 9,	53
January 10,	52
January 11,	52
January 12,	50
January 13,	48
January 14,	41
January 15,	44
January 16,	49
January 17,	48
January 18,	47
January 19,	49
January 20,	49
January 21,	45
January 22,	40
January 23,	39
January 24,	45
January 25,	49
January 26,	47
January 27,	40
January 28,	40
January 29,	44
January 30,	47
January 31,	44
February 1,	43
February 2,	42
February 3,	43
February 4,	44
February 5,	40
February 6,	45
February 7,	58
February 8,	56
February 9,	43
February 10,	48
February 11,	60
February 12,	65
February 13,	59
February 14,	44
February 15,	43
February 16,	48
February 17,	48
February 18,	50
February 19,	53
February 20,	52
February 21,	49
February 22,	48
February 23,	44
February 24,	42
February 25,	45
February 26,	51
February 27,	47
February 28,	53
March 1,	59
March 2,	53
March 3,	38
March 4,	40
March 5,	41
March 6,	43
March 7,	48
March 8,	50
March 9,	50
March 10,	47
March 11,	57
March 12,	51
March 13,	51
March 14,	52
March 15,	50
March 16,	48
March 17,	46
March 18,	46
March 19,	49
March 20,	49
March 21,	51
March 22,	49
March 23,	49
March 24,	52
March 25,	55
March 26,	58
March 27,	53
March 28,	52
March 29,	52
March 30,	50
March 31,	53
April 1,	56
April 2,	57
April 3,	54
April 4,	50
April 5,	53
April 6,	60
April 7,	60
April 8,	61
April 9,	64
April 10,	59
April 11,	55
April 12,	53
April 13,	57
April 14,	58
April 15,	57
April 16,	55
April 17,	56
April 18,	57
April 19,	59
April 20,	61
April 21,	64
April 22,	65
April 23,	62
April 24,	59
April 25,	65
April 26,	67
April 27,	69

Neither the figures nor the graphic record (Plate VIII), show any evident relation between the stable-temperature and the results of these experiments as recorded in subsequent pages.

DRY MATTER AND NITROGEN EATEN.

As stated, the daily ration of hay was 6.35 kgs. From the analytical results on p. 76, are computed the amounts of air-dry matter, dry matter and nitrogen consumed per day and head, as follows:

Dry Matter, Air-dry Matter and Nitrogen of Feed per Day and Head.

When Fed.	Air-dry matter. Grms.	Dry matter. Grms.	Nitrogen. Grms.
Before December 13, 1894,	5,855	5,586	95.44
December 13-29, 1894,	5,760	5,533	85.44
December 20-26, 1894,	5,905	5,667	83.27
December 27, 1894-January 2, 1895,	6,001	5,721	82.83
January 3-9, 1895,	5,886	5,635	85.65
January 10-16, 1895,	5,886	5,536	82.70
January 17-23, 1895,	5,455	5,287	80.19
January 24-30, 1895,	5,709	5,531	84.21
January 31-February 6, 1895,	5,861	5,606	80.00
February 7-13, 1895,	5,829	5,598	83.90
February 14-20, 1895,	5,760	....	83.99
February 21-27, 1895,	5,785	....	84.17
February 28-March 6, 1895,	5,594	....	83.52
March 7-13, 1895,	5,486	....	79.27

DIGESTIBILITY.

As regards the air-dry matter and the nitrogen, the whole experiment, with the exception of the interval from Feb. 15th to March 6th, is a continuous digestion experiment. The time between March 6th, when the collection of the excreta was resumed, and the beginning of Experiment VII, with hay and starch, is so short as to be of questionable value. Omitting, likewise, the first week after the change from mixed hay to timothy hay, and taking the period from this date to February 13th, when the last of the 9th lot of hay weighed out was eaten, we have the results of 56 days from which we compute the following average digestibility of air-dry matter and nitrogen. The amounts of feces adhering to the rubber duct were so small as to be of no material influence upon the results for so long a period.

December 20----February 13.

	Air-dry Matter. Grms.	Nitrogen. Grms.
STEER 1:		
Eaten,	325,724	4,674.18
Excreted,	135,820	2,042.15
Digested,	189,904	2,632.03
Per cent. digested,	58.30	56.31
STEER 2:		
Eaten,	325,724	4,674.18
Excreted,	131,991	2,004.59
Digested,	193,733	2,669.59
Per cent. digested,	59.48	57.11
STEER 3:		
Eaten,	325,724	4,674.18
Excreted,	139,030	2,013.99
Digested,	186,694	2,660.19
Per cent. digested,	57.31	56.91
SUMMARY. PERCENTAGE DIGESTIBILITY:		
Steer 1,	58.30	56.31
Steer 2,	59.48	57.11
Steer 3,	57.31	56.91

As is frequently the case, we find differences in the digestibility of the ration by the different animals which, in view of the length of the period, can hardly be explained otherwise than as indicating individual differences in digestive capacity. The digestibility of the air-dry matter is greater the heavier the animal, but this is not true as regards the nitrogen, although the heaviest steer, No. 2, shows somewhat the highest digestibility. The differences in this respect, however, are less than those for the air-dry matter.

SPECIAL DIGESTION PERIOD.

The days from January 12-18, inclusive, constituted a special digestion period, aliquot samples of the air-dry feces being combined and subjected to a complete fodder analysis. For reasons to be stated later in connection with a consideration of variations in digestibility, the excretion has been compared with the food of three days previous. In the computations which follow, the weights of air-dry matter, dry matter and nitrogen of the food are as given on page 79. The dry matter of the hay is assumed to have had the composition given on page 76, with the exception of the percentage of total nitrogenous matter, which, as above stated, is computed from the percentage of nitrogen found in the samples for this particular period. It is assumed that the ratio of proteid to non-proteid nitrogen was the same as that found in the original samples, p. 76, and the nitrogen-free extract is computed by difference.

The composition of the combined samples of feces was as follows:

Percentage Composition of Feces.

	Steer 1.	Steer 2.	Steer 3.
AIR-DRY:			
Water,	6.25	5.91	5.75
Ash,	7.39	8.06	7.89
Proteids,	8.78	8.69	8.16
Non-proteids,	0.75	0.75	1.03
Crude fiber,	32.70	32.99	33.27
Nitrogen-free extract,	40.84	40.54	41.01
Ether extract,	3.29	3.06	2.89
	100.00	100.00	100.00
Total nitrogen,	1.525	1.510	1.470
Proteid nitrogen,	1.405	1.390	1.305
Energy per gram, Cal.,	4.454	4.483	4.429
WATER-FREE:			
Ash,	7.88	8.57	8.37
Proteids,	9.37	9.23	8.66
Non-proteids,	.80	.80	1.09
Crude fiber,	34.88	35.06	35.30
Nitrogen-free extract,	43.56	43.09	43.51
Ether extract,	3.51	3.25	3.07
	100.00	100.00	100.00
Total nitrogen,	1.627	1.605	1.560
Proteid nitrogen,	1.499	1.477	1.385
Energy per gram, Cal.,	4.751	4.765	4.699

From these data we get the following results for the percentage digestibility of the several ingredients:

Per Day and Head.

	Fresh substance. Grms.	Air-dry matter. Grms.	Dry matter. Grms.	Ash. Grms.	Organic matter. Grms.	Total nitrogen x 6.25. Grms.	Proteids. Grms.	Non-proteids.* Grms.	Crude fiber. Grms.	Nitrogen-free extract. Grms.	Ether extract.	Energy. Cal.
STEER 1:												
Hay eaten, ...	6,350	5,886.0	5,550.1	362.4	5,187.7	519.5	492.9	26.6	1,908.7	2,610.2	149.3	24,565
Feces (average of 6 days),..	14,268	2,516.8	2,359.5	186.0	2,173.5	239.9	239.9	....	823.0	1,027.8	82.8	11,210
Digested, ...	....	3,369.2	3,190.6	176.4	3,014.2	279.6	253.0	26.6	1,085.7	1,582.4	66.5	13,355
Digested, per cent., ...	....	57.24	57.49	48.68	58.04	53.82	51.28	100.00	56.88	60.62	44.54	54.36
STEER 2:												
Hay eaten, ...	6,350	5,886.0	5,550.1	362.4	5,187.7	519.5	492.9	26.6	1,908.7	2,610.2	149.3	24,565
Feces (average of 7 days)..	12,444	2,400.4	2,258.6	193.5	2,065.1	226.6	226.6	....	791.8	973.2	73.5	10,762
Digested, ...	....	3,485.6	3,291.5	168.9	3,122.6	292.9	266.3	26.6	1,116.9	1,637.0	75.8	13,803
Digested, per cent., ...	....	59.22	59.31	46.61	60.12	56.38	53.98	100.00	58.52	62.72	50.77	56.18
STEER 3:												
Hay eaten, ...	6,350	5,886.0	5,550.1	362.4	5,187.7	519.5	492.9	26.6	1,908.7	2,610.2	149.3	24,565
Feces (average of 7 days)..	13,241	2,502.6	2,358.6	197.4	2,161.2	230.0	230.0	....	832.6	1,026.3	72.3	11,084
Digested, ...	....	3,383.4	3,191.5	165.0	3,026.5	289.5	262.9	26.6	1,076.1	1,583.9	77.0	13,481
Digested, per cent., ...	....	57.48	57.51	45.53	58.28	55.73	53.34	100.00	56.38	60.68	51.57	54.88

*Assumed to be completely digestible.

If we compute the total nitrogenous matter of the feces from the daily determinations of nitrogen instead of from the determination in the combined samples, we obtain the following results:

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Eaten,	519.5	519.5	519.5
Excreted,	237.5	223.7	221.1
Digested,	282.0	295.8	298.4
Per cent. digested,	54.28	56.94	57.41
Per cent., from page 81,	53.82	56.38	55.73
Difference,	0.46	0.56	1.68

The results for Steers 1 and 2 agree substantially with those previously computed, while in the case of No. 3 the difference is more considerable although still not serious.

Comparing the results for air-dry matter and nitrogen in the special digestion period with those in the whole period, Dec. 20-Feb. 13, we have the following results:

Percentage Digestibility.

	Air-dry Matter.		Nitrogen.	
	Jan. 12-18.	Dec. 20-Feb. 13.	Jan. 12-18.	Dec. 20-Feb. 13.
Steer 1,	57.24	58.20	53.82	56.31
Steer 2,	59.22	59.48	56.38	57.11
Steer 3,	57.48	57.31	55.73	56.91

The digestibility of the nitrogen in the special digestion period was less than the average for the whole time, and the same is true of the air-dry matter for Steer No. 1.

It may fairly be considered that the average results for the 56 days are more accurate than those for only seven days. Moreover, in the special digestion period, the digestibility of the dry matter was sensibly the same as that of the air-dry matter, thus indicating that the neglect of the hygroscopic moisture of the samples introduces no serious error and that the results on air-dry matter for the 56 days may safely be taken as representing substantially the true digestibility of the hay. This being the case, if we assume the relative digestibility of the several ingredients of the hay to remain the same, we may correct the above results for the special digestion period to the average digestibility of air-dry matter and nitrogen for the whole experiment. Since the variation of the special digestion period from the average appears to be due, in all probability, to variations in the excertion, we may properly make the correction upon the feces. Accordingly, in case of Steer 1, we assume that the proper amount of air-dry matter excreted would have been 41.70 per cent of the air-dry food, equal to 2454.4 grams, and that the nitrogen excreted would have been 43.69 per cent. of the nitrogen of the food, equal to 36.32 grams. Calculating the weights of dry matter, ash, crude fiber and ether extract from the composition of the feces as already given, and taking nitrogen-free extract by difference, we get the corrected results contained in the following table. In the case of Steers No. 2 and No. 3, the correction for the air-dry matter is so slight as not to be worth making. We may therefore assume simply that the nitrogen of the feces should have been 42.89 per cent. and 43.09 per cent. respectively of that of the food and make the corresponding correction in the amount of nitrogen-free extract. Carrying out these corrections, we have the following corrected figures for the percentage digestibility of the hay:

Corrected Digestibility.

	Air-dry matter. Grms.	Dry matter. Grms.	Ash. Grms.	Organic matter. Grms.	Total nitrogen x 6.25.	Proteids. Grms.	Non-proteids.* Grms.	Crude fiber.	Nitrogen-free extract. Grms.	Ether extract. Grms.	Energy. Cal.
STEER 1:											
Food,	5,886.0	5,550.1	362.4	5,187.7	519.5	492.9	26.6	1,908.7	2,610.2	149.3	24,565
Feces (corrected),	2,454.4	2,301.0	181.4	2,119.6	227.0	227.0	....	802.6	1,009.2	80.8	10,932
Digested,	3,431.6	3,249.1	181.0	3,068.1	292.5	265.9	26.6	1,106.1	1,601.0	68.5	13,633
Digested, per cent.,	58.30	58.52	49.95	59.14	56.31	53.95	100.00	57.95	61.34	45.88	55.50
STEER 2:											
Food,	5,886.0	5,550.1	362.4	5,187.7	519.5	492.9	26.6	1,908.7	2,610.2	149.3	24,565
Feces (corrected),	2,400.4	2,258.6	193.5	2,065.1	222.8	222.8	....	791.8	977.0	73.5	10,762
Digested,	3,485.6	3,291.5	168.9	3,122.6	296.7	270.1	26.6	1,116.9	1,633.2	75.8	13,803
Digested, per cent.,	59.22	59.31	46.61	60.13	57.11	54.80	100.00	58.52	62.58	50.77	56.12
STEER 3:											
Food,	5,886.0	5,550.1	362.4	5,187.7	519.5	492.9	26.6	1,908.7	2,610.2	149.3	24,565
Feces (corrected),	2,502.6	2,358.6	197.4	2,161.2	223.9	223.9	....	832.6	1,032.4	72.3	11,084
Digested,	3,383.4	3,191.5	165.0	3,026.5	295.6	269.0	26.6	1,076.1	1,577.8	77.0	13,481
Digested, per cent.,	57.48	57.51	45.53	58.28	56.91	54.58	100.00	56.38	60.45	51.57	54.88

*Assumed to be completely digestible.

DAILY RATIONS.

The table on p. 79 shows the amount of dry matter and nitrogen eaten during this experiment. Assuming the composition of the dry matter to be represented by the analysis given on p. 76, except as to nitrogen, we find the average daily amounts of the several crude nutrients consumed to have been those given in the first column of the following table. Applying the above corrected co-efficients to these amounts, we have the average amount digested by each animal, as given in the succeeding columns of the table. The results for total nitrogenous matter and for air-dry matter are, of course, identical with those on p. 79.

Average Daily Rations December 20, 1894 to February 13, 1895.

	Eaten. Grms.	Digested.		
		Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Ash,	363	181	169	165
Proteids,	495	267	271	270
Non-proteids,	27	27	27	27
Crude fiber,	1,914	1,109	1,120	1,079
Nitrogen-free extract,	2,617	1,605	1,638	1,582
Ether extract,	150	69	76	77
Total dry matter,	5,566	3,258	3,301	3,200
Air-dry matter,	5,817	3,391	3,459	3,334
Total organic matter,	5,203	3,077	3,132	3,035
Nutritive ratio,	....	1:10.9	1:10.9	1:10.6
Energy,	Cal. 24,635	Cal. 13,678	Cal. 13,840	Cal. 13,520

The data regarding the food given on p. 79 and those for the excretion contained in the appendix also afford the means of estimating the variations in the average amounts of air-dry matter and nitrogen digested daily throughout the experiment. For this purpose we make use of the ten-day averages. Subtracting from the average air-dry matter and nitrogen eaten that of the corresponding feces (allowing as before, and for the same reason, a period of three days for the passage of the food through the alimentary canal) gives the amount of each digested. The results of this computation are contained in the appendix, and are represented graphically on Plates VIII and IX.

PROTEID METABOLISM.

As already stated, the nitrogen excretion was determined daily in both feces and urine. The averages per day and head for the whole experiment are as follows:

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Nitrogen of food,	83.47	83.47	83.47
Nitrogen of feces,	36.47	35.79	35.96
Digested,	47.00	47.68	47.51
Nitrogen in urine,	42.33	41.21	44.86*
Gain by animal,	4.67	6.47	2.65
Equivalent proteids,	29.19	40.44	16.56

These figures show a not inconsiderable gain of proteids and a comparison of the daily results and ten-day averages for digested nitrogen and urinary nitrogen given in the appendix, and represented graphically in Plate IX, leads to the same conclusion. In general, the proteid metabolism follows the variations in the amount of nitrogen digested, although certain exceptions to this rule occur. These exceptions have an interesting bearing upon the cause of the apparent variations in the digestibility of the food which will be considered later.

ENERGY OF URINE.

During the special digestion period a uniform daily aliquot (1-100) of the urine was dried on powdered pumice stone at a gentle heat, and at the close of the period the residue was weighed, total nitrogen determined by the Kjeldahl method and total energy by the bomb calorimeter. The following table shows the results of these determinations:

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Weight of dried urine and pumice,	128	127	124
Per cent. of nitrogen,	1.875	1.895	1.670
	Cal.	Cal.	Cal.
Energy per gram of the dried urine and pumice,	0.373	0.360	0.216

The losses of nitrogen during the drying were, therefore, as follows:

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Nitrogen of urine:			
January 12,	39.87	47.68	43.16
January 13,	42.10	41.84	41.48
January 14,	lost.	39.17	lost.
January 15,	41.60	44.43	45.22
January 16,	37.96	43.30	44.96
January 17,	43.86	43.10	lost.
January 18,	45.07	lost.	45.76
	250.46	259.52	220.58
Nitrogen in samples taken for drying,	2.5046	2.5952	2.2058
Nitrogen in dried samples,	2.4000	2.4070	2.0710
Loss in drying,	0.1046	0.1882	0.1348

*During the last eight days of January the collection of the urine of No. 3 was interfered with by a series of accidents. This average covers December 20-January 23, and February 1-12.

Assuming that the loss of nitrogen in drying arose from a decomposition of urea, and reckoning one gram of nitrogen in urea equivalent to 5434 cal., the total energy of the samples of urine actually taken for drying was as follows:

Energy of Urine.

	Steer 1. Cal.	Steer 2. Cal.	Steer 3. Cal.
Energy in dried urine,	47.744	45.720	26.784
Energy equivalent to nitrogen lost,	0.568	1.028	0.732
Total,	48.312	46.748	27.516
Energy per gram of nitrogen excreted,	19.29	18.01	12.47

The determinations of energy in the dried urine were unsatisfactory, owing to the fact that it was necessary to add a considerable amount of naphthalene to the samples in order to secure satisfactory combustion in the calorimeter. Dr. Woods estimates the range of possible error in these determinations at 20 per cent. On this basis, the range of the results would be as follows:

Energy per gram Nitrogen excreted.

Steer 1,	17.38 Cal.	to 21.20 Cal.
Steer 2,	16.25 Cal.	to 19.77 Cal.
Steer 3,	11.26 Cal.	to 13.69 Cal.

While these errors are relatively large, the absolute amount of energy per day involved is fortunately not great, and the errors do not seriously affect the computations of the total metabolism in the body. No reason is apparent for the exceptionally low figure obtained for Steer No. 3. There is no reason to believe that it is due to analytical errors.

The total amount of energy contained in the urine, per day and head, on the average of the whole experiment, as computed from the nitrogen of the urine (first table on p. 86) was:

Steer 1,	817 Cal.
Steer 2,	742 Cal.
Steer 3,	554 Cal.

LIVE WEIGHTS.

The daily weighings and ten-day averages contained in the appendix, as well as the graphic representation of them in Plates X, XI and XII, show a slight but steady gain of weight throughout most of the experiment. This is interrupted by a falling off in weight during the period from Feb. 16th to March 5th, during which the steers were standing in ordinary stalls, followed by a gain in weight when they were returned to the experimental stalls, but the same feeding was not continued long enough after the latter date to determine whether the renewed gain would be permanent. Inasmuch, however, as the animals were on exclusive coarse feed and had scarcely any exercise, it is not impossible that there had been some accumulation of matter in the alimentary tract and that the somewhat greater amount of freedom allowed during this period resulted in an increased excretion of feces. If this is true, then the weights reached about Feb. 1st to 10th, are somewhat above the normal. Assuming this to be the case, and applying the graphic method, with the same reservations as before, to the interpretation of the live weight, we draw the broken lines of the plate to represent the average rate of gain, and obtain the following results:

Gain in Live Weight.

	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.
Average weight December 20,	448	492	430
Average weight March 10,	452	497	434
Gain,	4	5	4
Gain per day,	.0500	.0625	.0500

Computing the final results per day and head, we have the following:

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Gain of nitrogen,	4.67	6.47	2.65
Equivalent "flesh,"	131.50	182.30	74.64
Gain in weight,	50.00	62.50	50.00
Computed loss of fat,	81.50	119.80	24.64

Estimated Production of Methan.

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Crude fiber digested,	1,109	1,120	1,079
Nitrogen-free extract digested,	1,605	1,638	1,582
Total,	2,714	2,758	2,661
Estimated methan,	123.5	125.5	121.1
	Cal.	Cal.	Cal.
Equivalent energy,	1,636	1,663	1,604

Energy Per Day and Head.

	Steer 1.		Steer 2.		Steer 3.	
	Ingesta. Cal.	Egesta. Cal.	Ingesta. Cal.	Egesta. Cal.	Ingesta. Cal.	Egesta. Cal.
Food,	24,635	....	24,635	....	24,635	....
Loss from body:						
Fat (estimated),	773	....	1,137	....	234	....
Excreta:						
Feces,	....	10,962	....	10,796	....	11,115
Urine,	....	816	....	742	....	559
Methan (estimated),	....	1,636	....	1,663	....	1,604
Gain by body:						
Proteids,	....	167	....	232	....	95
For maintenance,	....	11,827	....	12,340	....	11,496
	25,408	25,408	25,772	25,772	24,869	24,869

Maintenance Ration Per Day.

	Average live weight. Kgs.	Energy.	
		Per head. Cal.	Per 500 kgs. Live weight. Cal.
Steer 3,	490	11,827	12,690
Steer 2,	430	12,340	12,510
Steer 1,	450	11,496	12,730

Experiment VII.

March 14th to April 23rd, 1895.—41 Days.

In this experiment commercial starch was substituted for a portion of the hay, the endeavor being to keep the total amount of digestible matter in the ration the same as in Experiment VI, an attempt which was not entirely successful. Unfortunately, too, circumstances compelled the discontinuance of the experiment at a rather early date, so that the results are of less value than they otherwise might have been. The methods and appliances used were the same as in Experiment VI.

Beginning March 14th, 1895, starch was gradually substituted for the hay, as follows:

	Hay.	Starch.
March 14th,	5,896 grms.	272 grms.
March 15th,	5,443 grms.	544 grms.
March 16th,	4,990 grms.	816 grms.

The last named ration was continued until March 27th, inclusive, samples of the feed being taken covering the period from the 21st to the 27th inclusive. At that date a preliminary estimate based upon the amount of air-dry matter excreted indicated that from 100 to 150 grams less digestible matter was being consumed than on the hay ration.

The feed was therefore changed, beginning on March 28th, to:

Timothy Hay II,	5,200 grams.
Starch,	800 grams.

This ration continued to April 23rd, 1895, inclusive.

The hay employed in Experiment VI, designated as I, was used until March 27th, 1895, inclusive. The supply being then exhausted, a second lot of hay was procured (designated as II). This hay was grown on the College Farm and was similar in quality to that previously used. It had been baled. The hay of six bales, of about 50 kgs. each, was cut two or three inches long and the cut hay taken away from the cutter with a shovel and spread over a clean floor to a depth of about 40 cm. It was then shoveled over twice, leaving it in the form of a rectangle. Two ditches were then cut transversely through it, each about midway between the centre and one end and about 30 cm. wide, giving two samples of about of 23 kgs. each. Each of these samples was mixed and again spread over the floor in a circular form about 15 cm. deep and a ditch about 22 cm. wide cut through the centre. The sample thus obtained was taken to the laboratory, where it was further ground, sub-sampled and analyzed. The composition of the dry matter of these two samples was as follows:

Composition of Dry Matter of Hay II.

	a.	b.	Average.
Ash,	5.48	5.81	5.65
Proteids,	7.42	7.69	7.56
Non-proteids,	1.12	1.25	1.18
Crude fiber,	32.57	31.09	31.83
Nitrogen-free extract,	50.41	51.37	50.89
Ether extract,	3.01	2.78	2.89
Total,	100.00	100.00	100.00
Total nitrogen,	1.365	1.431	1.398
Albuminoid nitrogen,	1.186	1.231	1.208
Energy per gram,	Cal. 4.509	....	....

This lot of hay was employed up to April 15th, 1895, inclusive. For the last eight days of the experiment, a third lot of hay (III) from the same lot as II was used. A sample of this hay was taken as it was being weighed out in advance for the eight days. In this sample water and total nitrogen were determined, and the percentages of the other ingredients were assumed to be the same as in Hay II. This hay was used until April 23d, 1895.

The following table shows the composition of the dry matter of these three lots of hay as compared with Jenkins & Winton's average for timothy hay.

Composition of Dry Matter.

	J. & W's Av.	Hay, I.	Hay, II.	Hay, III.
Ash,	5.1	6.53	5.65	....
Proteids,	6.8	8.15	7.56	7.87
Non-proteids,		.44	1.18	
Crude fiber,	33.5	34.39	31.83	....
Nitrogen-free extract,	51.7	47.80	50.89	....
Ether extract,	2.9	2.69	2.89	....
Total,	100.00	100.00	100.00	....
Energy per gram,	....	Cal. 4.426	Cal. 4.509	....

It will be seen from the above table that samples I and II were quite similar in composition except that the crude fiber of I was slightly higher than that of II. Both contained more nitrogen than average timothy hay, a fact which was due in large part to a slight admixture of clover. Hay III contained considerably less nitrogen than the other two samples.

As in Experiment VI, samples were taken for determination of dry matter and nitrogen as the hay was weighed out. The results for hay I have already been given on p. 76, in connection with the description of the method of sampling, but are repeated here for convenience along with the corresponding results on the other two lots:

Composition of Hay Samples taken during the Experiment.

When Fed.	Lost in air-drying. Per cent.	In Air-dry Matter.		Water in hay as sampled. Per cent.	Nitrogen in dry matter. Per cent.
		Moisture. Per cent.	Nitrogen. Per cent.		
Hay I.					
February 21-27, 1895,	8.90	....	1.455	....	....
February 28-March 6, 1895,	11.90	....	1.475	....	....
March 7-13, 1895,	13.60	....	1.445	....	....
March 21-27, 1895,	9.80	....	1.405	....	....
Hay II.					
March 28-April 3, 1895,	7.20	4.86	1.215	11.71	1.276
April 4-10, 1895,	5.20	6.53	1.020	11.39	1.091
April 11-15, 1895,	6.50	4.41	1.345	10.62	1.407
Hay III.					
April 16-23, 1895,	7.90	5.06	1.195	12.56	1.259

The starch used was commercial corn (maize) starch, purchased of the National Starch Mfg. Co., Buffalo, N. Y. It was weighed out in advance, usually for the same time as was the hay, and was sampled as weighed out, determinations of nitrogen and moisture being made in these samples. The results of these determinations were as follows:

Composition of Starch Samples.

When fed.	Moisture. Per cent.	Nitrogen. Per cent.
March 23-27, 1895,	....	.095
March 28-April 3, 1895,	6.83	.100
April 4-10, 1895,	6.95	.100
April 11-17, 1895,	8.17	.020
April 18-23, 1895,	8.04	.020

In the sample of April 11-17, a determination of the heat of combustion was made and also a determination of the ash, with the following results:

Ash, 0.48 per cent.
Energy per gram, 3780 cal.

The latter determination is equivalent to 4130 cal. per gram of dry organic matter, which corresponds quite closely to Stohmann & Langbein's* results, viz. 4182 cal.

The appliances used and the general methods employed were the same as in the previous experiment, and, as in that case, the detailed daily records are given in the appendix, the analytical results on the daily samples being the results of single determinations, while those on food and on the feces from the special digestion period are the mean of two accordant determinations.

DRY MATTER AND NITROGEN EATEN.

The following table shows the amounts of air-dry matter, dry matter and total nitrogen per day and head contained in the daily rations:

Dry-matter, Air-dry Matter and Nitrogen of Feed per Day and Head.

When fed.	Air-dry Matter.		Dry Matter.		Nitrogen.	
	Hay. Grms.	Starch. Grms.	Hay. Grms.	Starch. Grms.	Hay. Grms.	Starch. Grms.
March 21-27, 1895,	4,501	816	....	....	63.24	0.78
March 28-April 3, 1895,	4,326	800	4,592	745	58.64	0.80
April 4-10, 1895,	4,929	800	4,608	744	50.28	0.80
April 11-15, 1895,	4,862	800	4,648	735	65.40	0.16
April 16-23, 1895,	4,789	800	4,547	736	57.23	0.16

DIGESTIBILITY.

From the date (March 28th) when the final ration was settled upon, the whole experiment is a continuous digestion trial as regards air-dry matter and nitrogen. The following table shows the total amounts eaten, excreted and digested. In computing the digestibility of the hay, it has been assumed that all the starch, including its nitrogen, was digested. The latter assumption may perhaps be of questionable propriety, but the absolute amount of nitrogen involved is so small as to be of little practical significance:

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*U. S. Dept. Agr., Office of Expt. Stations, Bul. 21, p. 129.

March 28th to April 23d, 1895.

	Air-dry matter. Grams.	Nitrogen. Grams.
EATEN BY EACH ANIMAL:		
Hay,	130,907	1,547.28
Starch,	21,600	13.28
Total,	152,507	1,560.56
STEER 1:		
Excreted,	54,866	746.00
Digested,	97,641	814.56
Per cent. digested,	64.02	52.19
Digested from hay,*	76,041	801.28
Per cent. digested,	58.09	51.77
STEER 2:		
Excreted,	55,608	794.33
Digested,	96,899	766.23
Per cent. digested,	63.53	49.09
Digested from hay,*	75,299	752.95
Per cent. digested,	57.52	48.65
STEER 3:		
Excreted,	58,885	781.82
Digested,	93,622	778.74
Per cent. digested,	61.39	49.89
Digested from hay,*	72,022	765.46
Per cent. digested,	55.02	49.46
SUMMARY: PERCENTAGE DIGESTIBILITY:		
Total Ration.		
Steer 1,	64.02	52.19
Steer 2,	63.53	49.09
Steer 3,	61.39	49.89
Hay Alone.*		
Steer 1,	58.09	51.77
Steer 2,	57.52	48.65
Steer 3,	55.02	49.46

The total air-dry matter in this ration was naturally more digestible than in the case of the hay ration in Experiment VI, but the digestibility of the air-dry matter of the hay is about two per cent. less in the cases of Steers 2 and 3 than when similar hay was fed alone. In the case of No. 1, on the other hand, it is not materially changed. The digestibility of the nitrogen of the hay was diminished by the addition of starch by about 4 per cent. in the case of Steer No. 1, and by about 8 per cent. in the cases of Steers No. 2 and 3. Evidently the digestive process in Steer No. 1 was less affected by the starch than in the case of the other animals, thus affording another instance of the individual differences in animals. Owing to the fact that the digestion of No. 1 was less affected by the starch, he stands at the head of the list in this period as regards digestive power.

Special Digestion Period.

The air-dry feces of April 13-19, inclusive, were united in aliquot proportions and analyzed, with the following results:

---

*Assuming starch to have been entirely digested.

Composition of Feces, April 13 19, 1895.

	Steer 1.	Steer 2.	Steer 3.
AIR-DRY:			
Water,	6.07	5.80	6.30
Ash,	7.11	6.93	6.49
Proteids,	8.25	8.34	7.85
Non-proteids,	.06	.13	.03
Crude fiber,	32.21	32.43	33.48
Nitrogen-free extract,	42.61	43.23	42.56
Ether extract,	3.69	3.14	3.29
	100.00	100.00	100.00
Total nitrogen,	1.330	1.355	1.260
Proteid nitrogen,	1.320	1.335	1.255
	Cal.	Cal.	Cal.
Energy per gram,	4.507	4.559	4.485
WATER-FREE:			
Ash,	7.57	7.36	6.93
Proteids,	8.78	8.86	8.37
Non-proteids,	.07	.13	.04
Crude fiber,	34.29	34.43	35.73
Nitrogen-free extract,	45.36	45.89	45.42
Ether extract,	3.93	3.33	3.51
	100.00	100.00	100.00
Total nitrogen,	1.416	1.438	1.345
Proteid nitrogen,	1.405	1.417	1.339
	Cal.	Cal.	Cal.
Energy per gram,	4.798	4.840	4.787

Comparing, as in Experiment VI, the excretion with the food of three days before, we have the following results for the percentage digestibility of the several ingredients in the special digestion period:

Per Day and Head.

	Fresh substance. Grms.	Air-dry matter. Grms.	Dry matter. Grms.	Ash. Grms.	Organic matter. Grms.	N. x. 6.25. Grms.	Proteids. Grms.	Non-proteids. Grms.	Crude fiber. Grms.	Nitrogen-free extract. Grms.	Ether extract. Grms.	Energy. Cal.
STEER 1:												
Hay, ...	5,200	4,861.0	4,627.4	261.5	4,365.9	388.0	335.6	52.4	1,472.9	2,371.3	133.7	20,866
Starch, ...	800	800.0	736.0	3.8	732.2	1.5	1.5	....	....	730.7	....	3,024
Total food,*	6,000	5,661.0	5,363.4	265.3	5,098.1	389.5	334.1	52.4	1,472.9	3,102.0	133.7	23,890
Feces, ...	10,907	2,054.4	1,929.7	146.1	1,783.6	170.7	170.7	0.0	661.8	875.3	75.8	9,259
Digested, ...	....	3,606.6	3,433.7	119.2	3,314.5	218.8	166.4	52.4	811.1	2,226.7	57.9	14,631
Per cent. digested, ...	....	63.71	64.02	44.93	65.02	56.17	49.36	100.00	55.06	71.78	43.31	61.25
Digested from hay,†	....	2,806.6	2,697.7	115.4	2,582.3	217.3	164.9	52.4	811.1	1,496.0	57.9	11,607
Per cent. digested,†	....	57.74	58.29	44.13	59.14	56.00	49.13	100.00	55.06	63.09	43.31	55.64
STEER 2:												
Total food as above,*	6,000	5,661.0	5,363.4	265.3	5,098.1	389.5	337.1	52.4	1,472.9	3,102.0	133.7	23,890
Feces, ...	10,463	2,052.1	1,933.1	142.2	1,790.9	173.8	173.8	0.0	665.5	887.2	64.4	9,356
Digested, ...	....	3,608.9	3,430.3	123.1	3,307.2	215.7	163.3	52.4	807.4	2,214.8	69.3	14,534
Per cent digested, ...	....	63.75	63.96	46.40	64.88	55.38	48.44	100.00	54.82	71.40	51.83	60.84
Digested from hay,†	....	2,808.9	2,694.3	119.3	2,575.0	214.2	161.8	52.4	807.4	1,484.1	69.3	11,510
Per cent. digested,†	....	57.79	58.22	45.63	58.98	55.20	48.21	100.00	54.82	62.58	51.83	55.16
STEER 3:												
Total food as above,*	6,000	5,661.0	5,363.4	265.3	5,098.1	389.5	337.1	52.4	1,472.9	3,102.0	133.7	23,890
Feces, ...	12,679	2,174.9	2,037.9	141.1	1,896.8	171.4	171.4	0.0	728.2	925.6	71.6	9,756
Digested, ...	....	3,486.1	3,325.5	124.2	3,201.3	218.1	165.7	52.4	744.7	2,176.4	62.1	14,134
Per cent. digested, ...	....	61.58	62.01	46.82	62.80	55.99	49.16	100.00	50.56	70.16	46.45	59.16
Digested from hay,†	....	2,686.1	2,589.5	120.4	2,469.1	216.6	164.2	52.4	744.7	1,445.7	62.1	11,110
Per cent. digested,†	....	55.26	55.96	46.04	56.55	55.82	48.98	100.00	50.56	60.96	46.45	53.24

*April 10-16, 1895, inclusive.

†Assuming starch to be wholly digestible.

Computing the digestibility of the total nitrogenous matter from the daily determinations of nitrogen in the feces of these seven days instead of from the analysis of the mixed sample, we have the following results:

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
In food,	389.5	389.5	389.5
In feces,	171.4	181.3	177.9
Digested,	215.1	208.2	201.6
Per cent. digested,	55.22	53.46	51.76
Per cent. digested, p. 95,	56.17	55.38	55.99

The difference, especially in the cases of Nos. 2 and 3, is considerable. Repetition of the analyses confirmed their accuracy, and since a loss of nitrogen from the feces after air-drying seems very unlikely, the most probable explanation is some error in making up the mixed sample. Inasmuch, however, as the final results on digestibility are based on the average results for the whole experiment, the error is less serious than would otherwise be the case.

As in the previous experiment the percentage digestibility of the air-dry matter and of the dry matter is substantially the same, thus showing that conclusions based upon the digestibility of the former may be safely applied to the latter also.

The following table gives a comparison of the results on air-dry matter and total nitrogen for the special digestion period, and for the whole experiment:

Percentage Digestibility.

	Air-dry Matter.		Nitrogen.	
	Apr. 13-19	Mch. 23-Apr. 22.	Apr. 13-19.	Mch. 23-Apr. 22.
Steer 1,	63.71	64.02	56.17	52.19
Steer 2,	63.75	63.53	55.38	49.06
Steer 3,	61.58	61.30	55.99	49.06

The digestibility of the air dry matter for the whole period and for the special digestion period agrees so closely that no correction appears necessary, but the results on nitrogen differ quite widely.

It appears probable that some error was made in sampling the two lots of hay fed on April 4-10 and April 11-15. The nitrogen content of the former appears abnormally low, and that of the latter rather high, as compared with the remaining results on Hay II (p. 91), while the results for the proteid metabolism as given below, fail to show any corresponding variation. The sample of April 11-15 covers most of the digestion period, and an error such as is suspected would explain the high apparent percentage digestibility of the nitrogen.

Evidently, the results on nitrogen are somewhat uncertain, but if we assume that the average results for the whole period most correctly represent the digestibility of this ingredient and increase the figures for the amount excreted accordingly (decreasing the amount of indigestible nitrogen-free extract by a corresponding amount) we have the following corrected figures for the digestibility of the total nitrogenous matter, proteids and nitrogen-free extract:

	N. x. 6.25. Grms.	Proteids. Grms.	Nitrogen-free extract. Grms.
STEER 1:			
Hay,	388.0	335.6	2,371.3
Starch,	1.5	1.5	730.7
Total food,	389.5	337.1	3,102.0
Feces (corrected),	186.2	186.2	859.8
Digested,	203.3	150.9	2,242.2
Per cent. digested,	52.19	44.77	72.29
Digested from hay,*	201.8	149.4	1,511.5
Per cent. digested,*	52.01	44.52	63.74
STEER 2:			
Total food as above,	389.5	337.1	3,102.0
Feces (corrected),	198.3	198.3	862.7
Digested,	191.2	138.8	2,239.3
Per cent. digested,	49.09	41.18	72.20
Digested from hay,*	189.7	137.3	1,508.6
Per cent. digested,*	48.89	40.91	63.62
STEER 3:			
Total food as above,	389.5	337.1	3,102.0
Feces (corrected),	195.2	195.2	901.8
Digested,	194.3	141.9	2,200.2
Per cent. digested,	49.89	42.09	70.93
Digested from hay,*	192.8	140.4	1,469.5
Per cent. digested,*	49.69	41.83	61.97

With the above corrections, the co-efficients of digestibility would be as follows:

---

*Assuming starch to be wholly digestible.

Corrected Coefficients.

	Air-dry matter. Grms.	Dry matter. Grms.	Ash. Grms.	Organic matter. Grms.	N. x. 6.25. Grms.	Proteids. Grms.	Non-proteids. Grms.	Crude fiber. Grms.	Nitrogen-free extract. Grms.	Ether extract. Grms.	Energy. Cal.
TOTAL FOOD:											
Steer 1,	63.71	64.02	44.93	65.02	52.19	44.77	100	55.06	72.29	43.31	61.25
Steer 2,	63.75	63.96	46.40	64.88	49.00	41.18	100	54.82	72.20	51.83	60.84
Steer 3,	61.58	62.01	46.82	62.80	49.89	42.09	100	50.56	70.93	46.45	59.16
HAY:											
Steer 1,	57.74	58.29	44.13	59.14	52.01	44.52	100	55.06	63.74	43.31	55.64
Steer 2,	57.79	58.22	45.62	58.98	48.89	40.91	100	54.82	63.52	51.83	55.16
Steer 3,	55.26	55.96	46.04	56.55	49.69	41.83	100	50.56	61.97	46.45	53.24
HAY IN EXPERIMENT VI.											
Steer 1,	58.30	58.52	49.95	59.14	56.31	53.95	100	57.95	61.34	45.88	55.50
Steer 2,	59.22	59.31	46.61	60.13	57.11	54.80	100	58.52	62.58	50.77	56.18
Steer 3,	57.48	57.51	45.53	58.28	56.91	54.58	100	56.38	60.45	51.57	54.88

While the hay used in this experiment was not the same as that used in Experiment VI, the two were so similar that we may fairly assume that there would have been no serious difference in their digestibility. On this assumption, the starch appears to have had little effect on the digestibility of the hay aside from the somewhat uncertain results upon the nitrogen. The digestibility of the crude fiber has been slightly diminished but, on the other hand, that of the nitrogen-free extract appears to have been increased somewhat, although it is of course possible that this may be due to difference in the hay. These results were somewhat unexpected and are hardly in accord with those of similar trials elsewhere.

DAILY RATIONS.

The table on p. 92 shows the amount of dry matter and nitrogen eaten during the experiment. Assuming the composition of the dry matter to be that shown by the first table, p. 91, except as to nitrogen, we find the amounts of the several crude nutrients to have been those given in the first column of the following table. Applying the above corrected coefficients to these amounts, we have the average quantities digested by each animal per day and head, as given in the succeeding columns of the table. The results for total nitrogenous matter and for air-dry matter are, of course, identical with those on p. 93.

Average Daily Rations, March 28th to April 23d, 1895.

		Digested.		
	Eaten. Grms.	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Ash,	264	119	123	124
Proteids,	312	140	128	131
Non-proteids,	49	49	49	49
Crude fiber,	1,462	805	802	739
Nitrogen-free extract,	3,113	2,250	2,248	2,208
Ether extract,	133	58	69	62
Total dry matter,	5,333	3,421	3,419	3,313
Air-dry matter,	5,648	3,616	3,589	3,468
Total organic matter,	5,069	3,293	3,285	3,181
Nutritive ratio,		1:23.0	1:25.3	1:23.1
	Cal.	Cal.	Cal.	Cal.
Energy,	23,756	14,551	14,453	14,054
Energy per gram of air-dry matter digested,		4.02	4.03	4.05

By the same method employed in the previous experiment, we may also compute the average amounts of air-dry matter and nitrogen contained in the food digested daily throughout the experiment, with the results recorded in the appendix and represented graphically on Plates VIII and IX.

PROTEID METABOLISM.

As already noted, the results as regards nitrogen are somewhat questionable, owing to an apparent error in sampling. Taking the figures as they stand, however, we have as the average of the whole experiment the following results per day and head:

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Nitrogen of food,	57.80	57.80	57.80
Nitrogen of feces,	27.63	29.42	28.96
Digested,	30.17	28.38	28.84
Nitrogen of urine,	24.48	24.40	24.69
Gain by animal,	5.68	3.98	4.15
Equivalent proteids,	35.50	24.88	25.94

The gain of nitrogen by the animal was fully as great as that upon the ration of the previous experiment, notwithstanding the decreased amount consumed in the food, a fact which may perhaps be accounted for by the considerably wider nutritive ratio in this period. From the ten-day averages for the nitrogen digested and urinary nitrogen recorded in the Appendix and represented in Plate IX, it appears that during the time when the nitrogen of the food was decreasing the proteid metabolism closely followed it. During the last three weeks of the period, however, covering the time of uniform feeding, discrepancies appear, the amount of metabolism at one or two points equalling or even exceeding the amount digested from the food, while during the last few days of the experiment it falls very much below the latter. As already explained, these discrepancies are thought to be due to an error in sampling the hay.

ENERGY OF URINE.

The energy of the urine was determined in the same way as in the preceeding experiment, but owing to an unfortunate confusion of samples the results for Steers Nos. 2 and 3 were rendered worthless. The samples taken from Steer No. 1 during the digestion period were lost, and a second set of six samples was taken April 18-23 inclusive, so that the results on the proteid metabolism do not cover the same time as the special digestion period.

The results on Steer No. 1 were as follows:

Weight of dried urine and pumice,	121 grms.
Per cent. of nitrogen,	0.985 per cent.
Energy per gram,	0.251 Cal.

The loss of nitrogen during drying was:

	Nitrogen of Urine.
April 18,	19.05 grms.
April 19,	18.97 grms.
April 20,	18.50 grms.
April 21,	24.11 grms.
April 22,	19.60 grms.
April 23,	21.77 grms.
	122.00

Nitrogen in samples taken for air-drying,	1.2200 grms.
Nitrogen in dried samples,	1.1920 grms.
Lost in drying,	.0280 grms.

Assuming, as before, that the loss of nitrogen in drying arose from a decomposition of urea, we have the following results for the energy of the samples of urine actually taken for drying:

Energy in dried urine (0.251x121),	30.371 Cal.
Energy equivalent to nitrogen lost,	.152 Cal.
Total,	30.523 Cal.
Energy per gram of nitrogen excreted,	25.02 Cal.

The same statements as to the possible range of error in the determinations of energy which were made in connection with Experiment VI apply to this result also. The rations of the three animals having been identical, we may probably assume without risk of serious error that the energy per gram of nitrogen excreted was the same in all three cases and the subsequent computations have been made on this basis.

LIVE WEIGHTS.

As appears from the figures of the appendix and from Plates X, XI and XII, the course of the live weight varied somewhat in the different animals. In No. 1 the weight fell off steadily for several days after the change of feed and then increased at a pretty uniform rate. In No. 2 the live weight showed a slight but fairly constant increase after the change of feed, while No. 3 showed a somewhat irregular loss of weight.

Assuming, as in the previous cases, that the actual course of the live weight is fairly represented by the broken lines of the chart, we may make the following computations:

	Steer 1. Kgs.	Steer 2. Kgs.	Steer 3. Kgs.
Live weight, March 28th,	450.5	496.0	431.0
Live weight, April 17th,	453.0	497.0	427.0
Difference,	+2.5	+1.0	—4.0
Per day (÷ 20),	+0.125	+0.050	—0.200

Estimated Formation of Methan.

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Crude fiber digested,	806	802	739
Nitrogen-free extract digested,	2,250	2,248	2,208
Total,	3,056	3,050	2,947
Estimated methan,	139.0	138.8	134.1
	Cal.	Cal.	Cal.
Equivalent energy,	1,841	1,839	1,776

Per Day and Head.

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Gain of nitrogen,	5.68	3.98	4.15
Equivalent "flesh,"	160.00	121.1	116.9
Gain or loss of weight,	+125.00	+50.0	—200.0
Computed loss of fat,	35.0	62.1	316.9

Energy per Day and Head.

	Steer 1.		Steer 2.		Steer 3.	
	Ingesta. Cal.	Egesta. Cal.	Ingesta. Cal.	Egesta. Cal.	Ingesta. Cal.	Egesta. Cal.
Food	23,756	....	23,756	....	23,756	....
Loss from body:						
Fat (estimated),	332	....	589	....	3,006	....
Excreta:						
Feces,	....	9,206	....	9,303	....	9,702
Urine,	....	612	....	610	....	618
Methan (estimated),	....	1,841	....	1,839	....	1,776
Gain by body:						
Proteids,	....	203	....	142	....	149
For maintenance,	....	12,227	....	12,421	....	14,507
	24,088	24,088	24,345	24,345	26,752	26,752

Maintenance Rations per Day.

	Average live-weight.	Energy.	
		Per head. Cal.	Per 500 kgs. live-weight. Cal.
Steer 1,	450	12,227	13.110
Steer 2,	490	12 451	12,628
Steer 3,	430	14,507	16,040

As was to have been expected from the brevity of the experiment, the results are not as concordant as those of Experiment VI. This is especially true of Steer No. 3, the difference arising from the very marked loss of weight by this animal on a ration which sufficed to maintain the other two.

EXPERIMENTS OF 1896-97.

Experiment VIII.

December 27, 1896, to April 1, 1897—96 Days.

The two objects of this experiment were, first, to secure further data as to the maintenance ration and, second, to ascertain the effect upon the amount required for maintenance of supplying as large a portion of the digestible food as practible in the form of grain. For this purpose, the necessary bulk was supplied by wheat straw (of winter wheat), this being the least digestible coarse fodder available. Of this, 2 kgs. per day and head were fed, estimated to contain about 750 grams of digestible organic matter, while the remainder, amounting to from 2,250 to 2,550 grams, was derived from a mixture of corn (maize) meal and old process linseed meal. It was not attempted to keep a continuous record of the excretion, as in the experiments of 1895-6, but great care was taken to make the ration as uniform as possible, and two digestion trials were made, each 14 days long and separated by an interval of nearly four weeks.

ANIMALS.

The same three steers were used in this experiment as in the previous ones of the series. During the time intervening between Experiments VII and VIII, they were pastured during the summer and were fed on hay during the winter.

APPLIANCES AND METHODS.

The appliances and methods were substantially those of Experiments VI and VII. During most of the time the animals stood in ordinary stalls arranged so as to prevent loss of food or consumption of bedding. Three days before the beginning of each digestion trial they were placed in the special stalls previously described.

The analytical methods were those of the Association of Official Agricultural Chemists. The nitrogen of the urine was determined by the Kjeldahl method, and the energy in food and excreta by means of the bomb calorimeter.

Weighing and Sampling of Feeding Stuffs.—The straw was sampled in the same manner as the hay used in Experiment VI (compare p. 75), about 1,500 kgs., being cut up and stored.

The corn meal was sampled by mixing thoroughly about 900 kgs. of the unground grain, spreading it out on a clean floor and taking portions from 25 different points, amounting in all to about 20 kgs.; this amount was again spread out and a sub-sample of about 1 kg. drawn for analysis. The remainder of the grain was stored, and ground as needed for the experiment.

About 225 kgs. of the linseed meal was mixed, sampled and preserved in bags for the experiment.

During the experiment, the straw was weighed out for seven days in advance, in bags, and at each weighing a sample was drawn by taking a small handful from each bag. In this sample, dry matter and total nitrogen were determined, and in addition the two samples covering each of the two digestion periods were united and subjected to a complete fodder analysis.

The grain was weighed out daily, a small sample being set aside each time in a tight glass jar. The united samples for the seven days for which the straw was weighed out served for determination of dry matter and total nitrogen, and in the digestion trials the two samples were united and subjected to a complete fodder analysis.

The results of the determination of dry matter and total nitrogen in the several samples, were as follows:

Date.	Loss in air-drying. Per cent.	In Air-dry Matter.		Dry matter. Per cent.	Total N. in dry matter. Per cent.
		Moisture. Per cent.	Total nitrogen. Per cent.		
STRAW.					
Samples at beginning of experiment,	....	4.81	0.51	....	0.536
	....	3.20	0.57	....	0.589
January 15-21, 1897,	6.87	4.11	0.58	89.30	0.606
January 22-28, 1897,	9.00	2.87	0.61	88.39	0.628
January 29-February 4, 1897,	6.50	4.11	0.61	89.28	0.636
February 5-11, 1897,	7.33				
February 12-18,	7.60	2.90	0.60	89.68	0.639
February 19-25, 1897,	6.70	3.53	0.55	90.01	0.570
February 26-March 4, 1897,	7.50	3.37	0.55	89.38	0.569
March 5-11, 1897,	6.47	3.98	0.59	89.80	0.615
March 12-18, 1897,	5.67	3.79	0.58	90.12	0.603
March 19-25, 1897,	7.00				
March 26-April 1, 1897,	8.07	3.07	0.59	89.10	0.609
CORN MEAL.					
Sample at beginning of experiment,	....	5.43	1.66	....	1.755
January 15-21, 1897,	8.75	4.51	1.68	87.13	1.759
January 22-28, 1897,	7.75	4.73	1.69	87.88	1.774
January 29-February 4, 1897,	7 60	5.36	1.70	87.26	1.796
February 5-11, 1897,	8.00				
February 12-18, 1897,	9.00	4.04	1.68	87.32	1.751
February 19-25, 1897,	9.17	4.49	1.64	86.75	1.717
February 25-March 4, 1897,	8.43	3.62	1.69	88.25	1.753
March 5-11, 1897,	9.67	3.11	1.72	87.52	1.775
March 12-18, 1897,	7.17	3.36	1.72	88.26	1.780
March 19-25, 1897,	10.17				
March 26-April 1, 1897,	8.50	4.29	1.67	87.58	1.745
LINSEED MEAL.					
Sample at beginning of experiment,	....	2.94	6.12	....	6.306
January 15-21, 1897,	5.75	4.06	5.98	90.42	6.234
January 22-28, 1897,	4.50	4.11	6.12	91.57	6.333
January 29-February 4, 1897,	4.25	4.66	5.90	91.01	6.190
February 5-11, 1897,	4.83				
February 12-18, 1897,	5.17	4.09	6.06	90.95	6.319
February 19-25, 1897,	5.17	4.27	6.07	90.78	6.341
February 26-March 4, 1897,	4.83	4.31	6.00	91.07	6.270
March 5-11, 1897,	6.67	2.64	6.22	90.87	6.389
March 12-18, 1897,	4.17	3.69	6.04	91.47	6.272
March 19-25, 1897,	5.87				
March 26-April 1, 1897,	6.50	3.32	6.14	90.40	6.351

The results of the complete fodder analyses, calculated to the water-free state, were:

Percentage Composition..

	Ash. Per cent.	Proteids. Per cent.	Non-proteids. Per cent.	Crude fiber. Per cent.	Nitrogen-free extract. Per cent.	Ether extract. Per cent.	Energy per grm. Cal.
STRAW.							
Samples at beginning of experiment,	4.63 5.04	2.69 3.22	0.66 0.45	38.79 39.44	51.12 49.64	2.11 2.21	....
January 27-February 11, 1897,*	5.04	3.07	0.91	37.94	50.92	2.12	4.508
March 12-25, 1897,†	4.88	2.80	0.98	38.20	51.06	2.08	4.541
CORN MEAL.							
Sample at beginning of experiment.	1.37	10.37	0.59	2.10	80.97	4.60	....
January 29-February 11, 1897,*	5.35	36.19	2.50	7.56	41.71	6.69	4.794
March 12-25, 1897,†	5.20	35.96	3.24	7.52	41.49	6.59	4.835
LINSEED MEAL.							
Sample at beginning of experiment,	5.23	35.68	3.73	7.47	41.43	6.46	....
January 29-February 11, 1897,*	1.45	10.04	1.18	2.16	80.31	4.86	4.469
March 12-25, 1897,†	1.56	10.09	1.03	2.13	80.54	4.65	4.468

With the exception of a slightly greater percentage of nitrogen in the later samples of straw, the analyses agree closely, and indicate accurate sampling. The difference in the nitrogen of the straw is not serious, especially in view of the small absolute amount concerned.

Sampling of Excreta.—A uniform aliquot (1-100) of the feces was taken daily and preserved in the fresh state in a closed jar, with the addition of a few drops of carbon bisulfid. At the close of the digestion period the sample was mixed thoroughly and total nitrogen and pepsin-insoluble nitrogen determined in the fresh feces, the former by König's method, and the latter by G. Kühn's method. A portion was also air-dried at about 60 degrees C., and subjected to ordinary fodder analysis.

Similarly, 1-100 of the daily excretion of urine was set aside daily and total nitrogen determined by the Kjeldahl method in the mixed samples for the whole digestion period. No preservative was used in the urine, preliminary trials having shown no loss of nitrogen in several days standing.

In addition to the above, aliquot portions of the feces and urine were dried together at 60 degrees C., and used for determination of the energy of the total excreta, the loss of nitrogen during drying being controlled.

TEMPERATURE OF STABLE.

By an oversight the temperature record was not begun until January 29th. From that date it was recorded by a Draper metallic thermometer in the same manner as in Experiments VI and VII. The following were the average daily temperatures:

---

*First digestion trial.

†Second digestion trial.

Temperature of Stable—Degrees F.

1897.	Degrees.	1897.	Degrees.	1897.	Degrees.
January 29,	60	February 19,	49	March 12,	60
January 30,	58	February 20,	55	March 13,	58
January 31,	57	February 21,	55	March 14,	58
February 1,	59	February 22,	54	March 15,	59
February 2,	60	February 23,	50	March 16,	61
February 3,	60	February 24,	50	March 17,	61
February 4,	55	February 25,	49	March 18,	62
February 5,	58	February 26,	50	March 19,	63
February 6,	60	February 27,	49	March 20,	63
February 7,	59	February 28,	50	March 21,	69
February 8,	59	March 1,	49	March 22,	69
February 9,	61	March 2,	52	March 23,	70
February 10,	61	March 3,	52	March 24,	64
February 11,	62	March 4,	52	March 25,	59
February 12,	60	March 5,	53	March 26,	61
February 13,	59	March 6,	50	March 27,	59
February 14,	58	March 7,	49	March 28,	55
February 15,	55	March 8,	50	March 29,	60
February 16,	53	March 9,	52	March 30,	59
February 17,	54	March 10,	60	March 31,	58
February 18,	58	March 11,	63	April 1,	60

RATIONS FED.

The three steers were brought in from pasture October 9, 1896, and weighed on that date.

No. 1,	557.5 kgs.
No. 2,	652.3 kgs.
No. 3,	550.7 kgs.

They were placed on a ration of 5.kgs. (12 lbs.) of mixed clover and timothy hay and 0.68 kgs. (1½lbs.) of wheat bran, and on October 18th the daily weighings of the animals and of the water consumed were begun, the weights being taken at 1 p. m., as in former experiments. They were watered once daily.

As is shown by the records in the appendix and by Plates XIII, XIV and XV all three animals lost weight for a time, and in case of No. 3 the loss was very rapid. This animal was out of condition for the first two or three weeks of the experiment, being very constipated and refusing more or less of his feed. Two doses of Epsom salts were given him on Oct. 23d and 26th. On Nov. 5th his bran ration was increased to 0.91 kgs. (2 lbs.) and on Nov. 11th again increased to 1.82 kgs. (4 lbs.) The loss of weight still continuing, 0.45 kgs. (1 lb.) of corn meal was added to this ration on Nov. 15th. On Nov. 19th a gradual change toward the experimental ration was begun, Nos. 1 and 2 receiving 4.53 kgs. (10 lbs.) of hay and 0.91 kgs. (2 lbs.) of corn meal, and No. 3 the same with the addition of 1.82 kgs. (4 lbs.) of wheat bran. On Nov. 23d the rations were again changed to 2.72 kgs. (6 lbs.) of hay, 1.82 kgs. (4 lbs.) of corn meal, and 0.23 kgs. (½ lb.) linseed meal, with the addition, as before, of 1.82 kgs. (4 lbs.) of wheat bran in the case of No. 3. On Nov. 26th, the use of the experimental feeds was begun, the ration consisting of 2 kgs. wheat straw, 2.5

kgs. corn meal and 0.5 kgs. linseed meal, but the addition of wheat bran to the ration of No. 3 was continued, for the purpose of improving his general condition, until Dec. 10th.

From Nov. 26th the ration of straw was continued unchanged throughout the experiment but the amounts of grain were changed from time to time, in accordance with the indications of the live weight, in the endeavor to secure as nearly as possible a maintenance ration.

The following is a tabular record of these changes:

Rations Fed.

	Wheat straw. Kgs.	Corn meal. Kgs.	Linseed meal. Kgs.	Bran. Kgs.
STEER 1:				
December 1-16, 1896,	2	3.0	0.6	....
December 17, 1896-January 14, 1897,	2	2.5	0.5	....
STEER 2:				
December 1-26, 1896,	2	3.0	0.6	....
December 27, 1896-January 14, 1897,	2	2.75	0.5	....
STEER 3:				
December 1-9, 1896,	2	2.5	0.5	1.5
December 10-15, 1896,	2	3.0	0.6	....
December 16-26, 1896,	2	2.5	0.5	....
December 27, 1896-January 14, 1897,	2	2.75	0.5	....

The feeding stuffs used during this preliminary feeding were substantially of the same quality as those used in the experiment proper, but were not taken from the specially prepared lots described above, nor were any samples taken during the preliminary feeding. On January 15th the use of the specially prepared lots of feed was begun, the amounts fed being the same as those last recorded in the above table, viz:

	Wheat straw. Kgs.	Corn meal. Kgs.	Linseed meal. Kgs.
Steer 1,	2	2.5	0.5
Steer 2,	2	2.75	0.5
Steer 3,	2	2.75	0.5

These rations were continued unchanged until the close of the experiment on April 1st, samples being taken regularly as already described.

From the data already given regarding the composition of the feeding stuffs, we compute the amounts of dry matter and of total nitrogen consumed per day and head in the successive weeks of the experiment, to have been as follows:

Eaten per Day and Head.

	Dry Matter. Grms.				Total Nitrogen. Grms.			
	Straw.	Corn meal.	Linseed meal.	Total.	Straw.	Corn meal.	Linseed meal.	Total.
STEER 1.								
January 15-21, ...	1,786	2,178	452	4,416	10.81	38.31	28.18	77.30
January 22-28, ...	1,768	2,197	458	4,423	11.10	38.97	29.23	79.30
Jan. 29-Feb. 11 (digestion period), ...	1,785	2,181	455	4,421	11.35	39.17	28.16	78.68
February 12-18, ...	1,794	2,183	455	4,432	11.46	38.22	28.75	78.43
February 19-25, ...	1,800	2,169	454	4,423	10.26	37.24	28.79	76.29
February 26-March 4,	1,788	2,206	455	4,449	10.17	38.67	28.53	77.37
March 5-11, ...	1,796	2,186	454	4,436	11.06	38.84	29.01	78.91
March 12-25 (digestion period), ...	1,802	2,206	457	4,465	10.87	39.27	28.66	78.80
March 26-April 1, ...	1,782	2,190	452	4,424	10.85	38.21	28.71	77.77
Average,*	1,790	2,190	455	4,435	10.92	38.67	28.62	78.21
Average of two digestion periods, ...	1,794	2,194	456	4,444	11.11	39.22	28.41	78.72
STEERS 2 AND 3.								
January 15-21, ...	1,786	2,396	452	4,634	10.81	42.14	28.18	81.13
January 22-28, ...	1,768	2,417	458	4,643	11.10	42.88	29.23	83.21
Jan. 29-Feb. 11 (digestion period), ...	1,785	2,400	455	4,640	11.35	43.10	28.16	82.61
February 12-18, ...	1,794	2,401	455	4,650	11.46	42.04	28.75	82.25
February 19-25, ...	1,800	2,386	454	4,640	10.26	40.97	28.79	80.02
February 26-March 4,	1,788	2,427	455	4,670	10.17	42.54	28.53	81.24
March 5-11, ...	1,796	2,407	454	4,657	11.06	42.72	29.01	82.79
March 12-26 (digestion period), ...	1,802	2,427	457	4,686	10.87	43.20	28.66	82.73
March 26-April 1, ...	1,782	2,409	452	4,643	10.85	42.04	28.71	81.60
Average,*	1,790	2,409	455	4,654	10.92	42.54	28.62	82.08
Average of two digestion periods, ...	1,794	2,414	456	4,664	11.11	43.15	28.41	82.67

The variations from week to week are extremely small and the averages for the two digestion periods differ from those of the whole experiment by only 10 grms. of dry matter and 0.5 grms. of nitrogen, so that we may safely consider the results of the digestion periods as applicable to the whole experiment.

FIRST DIGESTION PERIOD.

January 29 to February 11, 1897.

The animals were placed in the special stalls on Jan. 25, and the collection of the feces and urine begun, but the latter were not weighed nor sampled until January 29th. On a few occasions the sample of urine was lost, owing to breakage of the apparatus. The feces were sampled only on the days when the urine sample was also available, in order that the sample of mixed feces and urine for determination of energy might be correctly taken. At the close of the digestion period the rubber ducts were hung in a cool place for several days and then weighed. The increase in weight over the original weight was taken to represent the air-dry feces adhering to them. The results were as follows:

---

*Digestion periods given double weight, since they cover two weeks.

	Total in 20 days. Grms.	Average per day. Grms.	Equivalent fresh feces per day. Grms.
Steer 1,	360	18	95
Steer 2,	1,020	51	283
Steer 3,	410	21	114

Probably the feces did not become as dry as the sample which was dried in the drying closet, and hence the above weight may be too large. In view of the small amount involved, however, the error cannot be material.

The following are the weights of the excreta, the urine including 200 cc. of distilled water used to rinse out the funnel.

Excretion.

	Steer 1.		Steer 2.		Steer 3.	
	Feces. Grms.	Urine. Grms.	Feces. Grms.	Urine. Grms.	Feces. Grms.	Urine. Grms.
January 29th,	7,740	2,870	5,340	4,450	(5,470)	Lost.
January 30th,	7,560	1,970	(8,240)	Lost.	10,040	2,890
January 31st,	(9,470)	Lost.	5,770	3,560	8,330	3,290
February 1st,	6,660	3,390	7,920	3,190	6,870	3,250
February 2d,	7,500	2,610	6,310	3,080	7,650	5,310
February 3d,	9,220	3,360	7,820	2,990	8,710	2,680
February 4th,	6,720	2,520	5,930	4,550	7,990	7,420
February 5th,	7,460	2,870	6,950	3,890	7,470	3,860
February 6th,	Lost.	Lost.	9,960	4,110	7,880	2,380
February 7th,	5,980	1,610	4,140	3,040	8,490	3,880
February 8th,	8,400	2,830	6,710	3,780	10,120	2,650
February 9th,	(6,680)	Lost.	(12,360)	Lost.	9,490	2,330
February 10th,	8,910	3,500	7,740	3,040	10,740	3,200
February 11th,	6,910	2,850	6,710	3,150	8,960	2,720
February 12th,	(8,360)	Lost.	8,590	3,720	9,150	4,980
February 13th,	7,720	Lost.	6,770	3,110	10,240	2,740
February 14th,	9,320	4,070	9,830	4,420	9,830	6,180
Total,*	92,380	34,450	106,490	54,080	141,960	59,760
Average per day,*	7,698	2,871	7,099	3,605	8,873	3,735
Air-dry weight,	1,452	....	1,277	....	1,635	....
Correction for duct,	18	....	51	....	21	....
Total daily excretion, air-dry,	1,470	....	1,328	....	1,656	....

The amount and composition of the food have already been stated (pp. 105 and 107). The analyses of the feces gave the following results:

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*Not including numbers in brackets.

Composition of Feces.

	Steer 1. Per cent.	Steer 2. Per cent.	Steer 3. Per cent.
IN FRESH FECES:			
Total nitrogen,	0.308	0.320	0.305
Pepsin-insoluble nitrogen,	0.171	0.187	0.164
Air-dry matter,	18.86	18.00	18.43
IN AIR-DRY FECES:			
Water,	5.46	5.09	4.76
Ash,	8.31	7.78	7.70
N x. 6.25,*	10.19	11.12	10.37
Crude fiber,	30.03	29.99	30.50
Nitrogen-free extract,	44.15	43.82	44.92
Ether extract,	1.86	2.20	1.75
	100.00	100.00	100.00
Total nitrogen,	1.480	1.580	1.465
Proteid nitrogen,	1.330	1.465	1.285
	Cal.	Cal.	Cal.
Energy per gram,	4.239	4.320	4.304

If the results of the digestion trials of 1894-5 were to be strictly followed, we should compare the food of Jan. 26-Feb. 11, with the feces of Jan. 29-Feb. 14. Since, however, the analysis of the food covers exactly the period from Jan. 29-Feb. 11, while there are several gaps in the collection of feces, the figures as given in the table have been used. The difference in any case would be insignificant, since the variations in the amounts of food eaten, as shown on p. 108, were very slight. For the sake of uniformity, the total nitrogenous matter (N x 6.25) of the feces has been regarded as indigestible proteids.

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*Computed from results on fresh feces.

Per Day and Head.

	Fresh substance. Grms.	Air-dry matter. Grms.	Dry matter. Grms.	Ash. Grms.	Organic matter. Grms.	N x. 6.25. Grms.	Proteids. Grms.	Non-proteids. Grms.	Crude fiber. Grms.	Nitrogen-free extract. Grms.	Ether extract. Grms.	Energy. Cal.
STEER 1.												
Eaten (Jan. 29-Feb. 11).												
Straw, ...	2,000	1,861.8	1,785.3	89.9	1,695.4	70.9	54.7	16.2	677.6	909.1	37.8	8,037.4
Corn meal, ...	2,500	2,305.0	2,181.4	31.6	2,149.8	244.8	219.0	25.8	47.0	1,752.0	106.0	9,747.8
Linseed meal, ...	500	477.3	455.1	24.3	430.8	176.1	164.7	11.4	34.4	189.8	30.5	2,181.3
	....	4,644.1	4,421.8	145.8	4,276.0	491.8	438.4	53.4	759.0	2,850.9	174.3	19,966.5
Feces (Jan. 29-Feb. 14), 12 days,	7,793	1,470.0	1,389.7	122.2	1,267.5	149.7	149.7	00.0	441.5	649.0	27.3	6,231.3
Digested, ...	....	3,171.1	3,032.1	23.6	3,008.5	342.1	288.7	53.4	317.5	2,201.9	147.0	13,735.2
Per cent. digested, ...	....	68.28	68.57	16.19	70.36	69.56	65.85	100.00	41.83	77.24	84.34	68.80
STEER 2.												
Eaten (Jan. 29-Feb. 11).												
Straw, ...	2,000	1,861.8	1,785.3	89.9	1,695.4	70.9	54.7	16.2	677.6	909.1	37.8	8,037.4
Corn meal, ...	2,750	2,535.5	2,399.6	34.7	2,364.9	269.3	240.9	28.4	51.7	1,927.3	116.6	10,722.6
Linseed meal, ...	500	477.3	455.1	24.3	430.8	176.1	164.7	11.4	34.4	189.8	30.5	2,181.3
	....	4,874.6	4,640.0	148.9	4,491.1	516.3	460.3	56.0	763.7	3,026.2	184.9	20,941.3
Feces (Jan. 29-Feb. 14), 15 days,	7,382	1,328.0	1,260.4	103.3	1,157.1	147.7	147.7	0.0	398.3	581.9	29.2	5,737.0
Digested, ...	....	3,546.6	3,379.6	45.6	3,334.0	368.6	312.6	56.0	365.4	2,444.3	155.7	15,204.3
Per cent. digested, ...	....	72.76	72.84	30.63	74.24	71.40	67.92	100.00	47.84	80.77	84.21	72.61
STEER 3.												
Eaten (Jan. 29-Feb. 11), same as Steer No. 2, ...	....	4,874.6	4,640.0	148.9	4,491.1	516.3	460.3	56.0	763.7	3,026.2	184.9	20,941.3
Feces (Jan. 30-Feb. 14), 16 days,	8,987	1,656.0	1,577.2	127.6	1,449.6	171.7	171.7	0.0	505.1	743.8	29.0	7,127.4
Digested, ...	....	3,218.6	3,062.8	21.3	3,041.5	344.6	288.6	56.0	258.6	2,282.4	155.9	13,813.9
Per cent. digested, ...	....	66.04	66.00	14.30	67.72	66.74	62.70	100.00	33.86	75.42	84.32	65.97

In this, as in previous experiments, Steer No. 2 shows a distinctly greater digestive capacity than No. 1, while No. 3 is inferior to both.

The determinations of the nitrogen in the feces, as given on p. 110, afford some data for a classification of the nitrogenous matters contained in them. As the results show, there was a loss of nitrogen in the air-drying of these feces. Computed on the air-dry feces, these losses were as follows:

Loss of Nitrogen in Air-drying of Feces.

	Steer 1. Per cent.	Steer 2. Per cent.	Steer 3. Per cent.
Total nitrogen of feces,	1.633	1.777	1.655
Nitrogen remaining after air-drying,	1.480	1.580	1.465
Loss,	0.153	0.197	0.190
Percentage loss,	9.37	11.09	11.48

On the probable assumption that the loss of nitrogen in drying was due to a decomposition of non-proteid nitrogenous matter, and that consequently the percentage of proteid nitrogen obtained by the analyses of the air-dry feces is correct, we can classify the nitrogen of the feces as follows:

Nitrogen of Feces per Day.

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Insoluble in pepsin,	13.38	13.82	13.91
Soluble in pepsin, precipitable by $Cu(OH)_2$,	6.17	5.64	7.37
Soluble in pepsin, not precipitable by $Cu(OH)_2$,	4.45	4.14	6.13
	24.00	23.60	27.41

It would seem that at least the nitrogenous matter not precipitable by copper hydrate must be metabolic products, since it is difficult to conceive how either the non-proteids of the food or any of the crystalline products of the action of trypsin on the proteids should escape absorption. The nitrogenous matters insoluble in pepsin are just as clearly food-residue (nucleins.) The intermediate class, however, viz., that soluble in pepsin and precipitable by copper hydrate, may consist of residues of food proteids which have escaped digestion, or of metabolic products, or in part of both. No attempt was made in this experiment to further separate this group. Even if we regard it as made up entirely of undigested food proteids, however, we find a much higher digestibility for the proteids than that computed in the conventional way, viz:

Digestibility of Proteid Nitrogen.

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
In food,	70.15	73.63	73.63
In feces,	19.55	19.46	21.28
Digested,	50.60	54.17	52.35
	Per cent.	Per cent.	Per cent.
Coefficients,	72.14	73.55	71.08

SECOND DIGESTION PERIOD.

March 12-28, 1897.

The steers were placed in the special stalls on March 10th, and the collection of the excreta begun, the weighing and sampling, however, beginning on the 12th. The trial was conducted in all respects like the preceding one, with the following results:

Correction for Feces adhearing to Ducts.

	Total in 19 days. Grms.	Average per day. Grms.	Equivalent fresh feces per day. Grms.
Steer 1,	40	2	9
Steer 2,	80	4	21
Steer 3,	280	15	78

Excretion.

	Steer 1.		Steer 2.		Steer 3.	
	Feces. Grms.	Urine. Grms.	Feces. Grms.	Urine. Grms.	Feces. Grms.	Urine. Grms.
March 12, 1897,	8,040	3,570	5,160	3,700	9,130	2,970
March 13, 1897,	....	....	6,080	2,980	8,240	5,210
March 14, 1897,	7,160	2,670	8,670	3,390	7,250	5,630
March 15, 1897,	....	....	6,120	3,260	7,730	2,270
March 16, 1897,	7,810	5,110	8,330	4,460	....	3,170
March 17, 1897,	7,150	3,900	....	....	9,480	....
March 18, 1897,	5,250	4,170	7,560	3,810	7,430	3,320
March 19, 1897,	8,530	4,670	5,060	4,440	10,440	3,000
March 20, 1897,	....	....	9,250	4,260	6,910	2,590
March 21, 1897,	7,450	2,780	6,410	3,370	6,640	5,400
March 22, 1897,	7,520	3,320	6,600	3,810	9,350	3,020
March 23, 1897,	....	....	5,240	5,720	6,580	7,160
March 24, 1897,	8,930	3,430	7,350	3,410	10,000	2,950
March 25, 1897,	....	....	5,240	5,720	6,580	7,160
March 26, 1897,	6,700	6,510	7,450	3,120	9,890	3,370
March 27, 1897,	5,530	7,410	7,200	3,730	6,660	3,370
March 28, 1897,	7,740	8,360	9,620	3,500	9,600	3,050
Total,	87,810	55,900	112,710	60,840	131,720	63,460
Average per day,	7,318	4,658	7,044	3,803	8,233	3,966
Air-dry weight,	1,547	....	1,339	....	1,576	....
Correction,	2	....	4	....	15	....
Total daily excretion, air-dry,	1,549	....	1,343	....	1,591	....

On several occasions Steer No. 1 broke or disarranged his urine funnel so that some of the urine was lost. As in the previous trial, both feces and urine for those days were discarded. Only one or two such losses occurred with the other two animals.

Composition of Feces.

	Steer 1. Per cent.	Steer 2. Per cent.	Steer 3. Per cent.
IN FRESH FECES:			
Total nitrogen,	0.365	0.372	0.346
Pepsin-insoluble nitrogen,	0.189	0.192	0.168
Air-dry matter,	21.14	19.00	19.14
IN AIR-DRY FECES:			
Water,	7.21	7.07	7.30
Ash,	7.84	6.67	7.09
N x. 6.25,*	10.79	12.23	11.30
Crude fiber,	30.09	29.60	30.02
Nitrogen-free extract,	41.90	42.08	42.39
Ether extract,	2.17	2.35	1.90
	100.00	100.00	100.00
Total nitrogen,	1.500	1.615	1.575
Proteid nitrogen,	1.285	1.450	1.410
	Cal.	Cal.	Cal.
Energy per gram,	4.176	4.332	4.179

*Computed from results on fresh feces.

Food Eaten and Digested Per Day and Head.

	Fresh substance. Grms.	Air-dry matter. Grms.	Dry matter. Grms.	Ash. Grms.	Organic matter. Grms.	Total N x 6.25. Grms.	Proteids. Grms.	Non-proteids. Grms.	Crude fiber. Grms.	Nitrogen-free extract. Grms.	Ether extract. Grms.	Energy. Cal.
STEER 1.												
Eaten (March 12-25),												
Straw,	2,000	1,873.4	1,802.3	87.8	1,714.5	68.0	50.4	17.6	688.5	920.6	37.4	8,183.8
Corn meal,	2,500	2,283.3	2,206.4	34.5	2,171.9	245.4	222.6	22.8	47.0	1,777.0	102.5	9,857.0
Linseed meal,	500	474.9	457.4	23.8	433.6	179.2	164.4	14.8	34.4	189.8	30.2	2,211.1
	....	4,631.6	4,466.1	146.1	4,320.0	492.6	437.4	55.2	769.9	2,887.4	170.1	20,251.9
Feces (March 12-28), 12 days,	7,327	1,549.0	1,437.8	121.4	1,315.9	167.1,	167.1	0.0	466.1	649.1	33.6	6,468.6
Digested,	....	3,082.6	3,028.3	24.7	3,004.1	325.5	270.3	55.2	303.8	2,238.3	136.5	13,783.3
Per cent. digested,	....	66.56	67.81	16.90	69.53	66.09	61.80	100.00	39.46	77.52	80.26	68.06
STEER 2.												
Eaten (March 12-25).												
Straw,	2,000	1,873.4	1,802.3	87.8	1,714.5	68.0	50.4	17.6	688.5	920.6	37.4	8,183.8
Corn meal,	2,750	2,511.6	2,427.0	37.9	2,389.1	269.9	244.8	25.1	51.8	1,964.7	112.7	10,842.6
Linseed meal,	500	474.9	457.4	23.8	433.6	179 2	164.4	14.8	34.4	189.8	30.2	2,211.1
	....	4,859.9	4,686.7	149.5	4,537.2	517.1	459.6	57.5	774.7	3,065.1	180.3	21,237.5
Feces (March 12-28), 16 days,	7,065	1,243.0	1,248.0	89.6	1,158.4	164.3	164.3	0.0	397.6	565.0	31.5	5,817.9
Digested,	....	3,616.9	3,438.7	59.9	3,378.8	352.8	295.3	57.5	377.1	2,500.1	148.8	15,419.6
Per cent. digested,	....	72.36	73.38	40.07	74.47	68.23	64.25	100.00	48.68	81.57	82.54	72.61
STEER 3.												
Eaten (March 12-25), same as Steer No. 2,	....	4,859.9	4,686.7	149.5	4,537.2	517.1	459.6	57.5	774.7	3,065.1	180.3	21,237.5
Feces (March 12-28), 16 days,	8,311	1,591.0	1,474.9	112.8	1,362.1	179.8	179.8	0.0	477.6	674.5	30.2	6,648.8
Digested,	....	3,268.9	3,211.8	36.7	3,175.1	337.3	279.8	57.5	297.1	2,390.6	150.1	68.70
Per cent. digested,	....	67.26	68.54	24.55	69.98	65.23	60.88	100.00	38.35	78.00	83.25	68.70

Loss of Nitrogen in Air-drying.

	Steer 1. Per cent.	Steer 2. Per cent.	Steer 3. Per cent.
Total nitrogen of feces computed to air-dry state,	1.727	1.957	1.808
Nitrogen remaining after air-drying,	1.500	1.615	1.575
Loss,	0.227	0.342	0.233
Percentage loss,	13.14	17.48	12.89

Nitrogen in Feces.

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Insoluble in pepsin,	13.85	13.56	13.96
Soluble in pepsin, precipitable by $Cu(OH)_2$,	6.05	5.91	8.46
Soluble in pepsin, not precipitable by $Cu(OH)_2$,	6.84	6.81	6.33
	26.74	26.28	28.75

*Digestibility of Proteid Nitrogen.**

	Steer 1.	Steer 2.	Steer 3.
In food,	69.98	73.53	73.53
In feces,	19.90	19.47	22.42
Digested,	50.08	54.06	51.11
	Per cent.	Per cent.	Per cent.
Coefficients,	71.57	73.52	69.44

The percentage digestibility of the ration in the two digestion periods is summarized in the following table:

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*On the same assumptions as before.

Percentage Digestibility.

	Dry matter.	Ash.	Organic matter.	Total N x. 6.25.	Proteids.	Non-proteids.	Crude	Nitrogen-free extract.	Ether extract.	Energy.
STEER 1:										
Period I,	68.57	16.19	70.36	69.56	65.85	(100)	41.83	77.24	84.34	68.80
Period II,	67.81	16.90	69.53	66.09	61.80	(100)	39.46	77.52	80.26	68.06
Average,	68.19	16.55	69.95	67.82	63.83	(100)	40.65	77.38	82.30	68.43
STEER 2:										
Period I,	72.84	30.63	74.24	71.40	67.92	(100)	47.84	80.77	84.21	72.61
Period II,	73.38	40.07	74.47	68.23	64.25	(100)	48.68	81.57	82.54	72.61
Average,	73.11	35.35	74.36	69.82	66.09	(100)	48.26	81.17	83.38	72.61
STEER 3:										
Period I,	66.00	14.30	67.72	66.74	62.70	(100)	33.86	75.42	84.32	65.97
Period II,	68.54	24.55	69.98	65.23	60.88	(100)	38.35	78.00	83.25	68.70
Average,	67.27	19.43	68.85	65.99	61.79	(100)	36.11	76.71	83.79	67.34

The agreement of the results of the two trials is very close in the cases of Nos. 1 and 2, and even with Steer 3 the differences, although more considerable, are still not so great as to be of very serious consequence. As regards individual ingredients, the greatest differences are found, as would be expected, in the figures for the ether extract and the nitrogenous matter. The corrected figures for proteid nitrogen, however, show a greater uniformity, viz:

Digestibility of Proteid Nitrogen.

	Steer 1. Per cent.	Steer 2. Per cent.	Steer 3. Per cent.
Period I,	72.14	73.55	71.08
Period II,	71.57	73.52	69.44

DAILY RATIONS.

In view of the close agreement in the results of the two digestion periods, and of the uniformity in the amounts and composition of the feed consumed, as shown on p. 108, the amounts of the several digestible nutrients consumed per day throughout the experiment may be safely considered to be the same as those actually digested in the two digestion periods. Averaging these amounts, then, we have the following figures for the average daily ration.

Average Daily Rations, January 15 to April 1, 1897.

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Total dry matter,	4,444.0	4,663.3	4,063.3
DIGESTIBLE:			
Ash,	24.2	52.8	29.0
Proteids,	279.5	303.9	284.2
Non-proteids,	54.3	56.8	56.8
Crude fiber,	310.6	371.2	277.9
Nitrogen-free extract,	2,220.1	2,472.2	2,336.4
Ether extract,	141.8	152.3	153.0
Dry matter,	3,030.5	3,409.2	3,137.3
Organic matter,	3,006.3	3,356.4	3,108.3
Nutritive ratio,	1:10.4	1:10.7	1:10.6
	Cal.	Cal.	Cal.
Energy,	13,759.3	15,312.0	14,201.3

As already noted, substantially the same rations were fed to No. 1 from Dec. 17, 1896, and to Nos. 2 and 3 from Dec. 27, 1896, up to the beginning of the experiment proper on January 15, 1897.

PROTEID METABOLISM.

The results of the determinations of nitrogen in the combined urine samples of the two digestion periods were as follows per day and head:

	Steer 1.	Steer 2.	Steer 3.
PERIOD I:			
Average weight of urine, grms.,	2,871	3,605	3,735
Per cent. nitrogen,	1.745	1.605	1.475
Weight of nitrogen, grms,	50.09	57.85	55.09
PERIOD II:			
Average weight of urine, grms.,	4,658	3,803	3,966
Per cent. of nitrogen,	1.205	1.525	1.480
Weight of nitrogen, grms,	56.13	58.00	58.70

Combining these results with those already given for the food and the feces, we obtain the following figures for the proteid metabolism expressed in terms of nitrogen:

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
PERIOD I:			
Nitrogen of food,	78.68	82.61	82.61
Nitrogen of feces,	24.00	23.60	27.41
Nitrogen digested,	54.68	59.01	55.20
Nitrogen of urine,	50.09	57.85	55.09
Nitrogen gained,	4.59	1.16	0.11
PERIOD II:			
Nitrogen of food,	78.80	82.73	82.73
Nitrogen of feces,	26.74	26.28	28.75
Nitrogen digested,	52.06	56.45	53.97
Nitrogen of urine,	56.13	58.00	58.70
Nitrogen lost,	4.07	1.55	4.73

While, as already pointed out, slightly less nitrogenous matter was apparently digested in the second period than in the first, there was, nevertheless, a marked increase in the urinary nitrogen, especially with Steer 1, so that an apparent gain of flesh in the first period is changed into an apparent loss in the second period. Nothing is apparent in the records of the experiment to explain this marked increase in the proteid metabolism, with the exception of an increase of about 3 kgs. per day in the amount of water consumed by Nos. 1 and 3. The temperature of the stable during the two periods was substantially the same.

If it be considered allowable to take the average of the two periods as representing the whole experiment, we shall have for the gain or loss of nitrogen per day and head:

Steer 1,	+0.26 grms.
Steer 2,	—0.20 grms.
Steer 3,	—2.31 grms.

ENERGY OF EXCRETA.

The determination of nitrogen and energy in the samples of feces and urine dried together gave the following results:

	Loss in air-drying. Per cent.	In air-dry matter.	
		Nitrogen. Per cent.	Energy per grm. Cal.
PERIOD I:			
Steer 1,	83.66	4.00	3.893
Steer 2,	86.00	3.45	3.697
Steer 3,	85.69	3.00	4.007
PERIOD II:			
Steer 1,	83.85	3.84	3.687
Steer 2,	83.92	4.44	3.788
Steer 3,	83.43	4.11	3.727

Energy of Excreta.

	Weight of Feces and Urine.		N. in air-dry excreta. Grms.	Total N. in excreta. Grms.	N. lost in air-drying. Grms.	Energy equivalent to N. lost. Cal.	Energy in air-dry excreta. Cal.	Total energy of excreta. Cal.	Energy of feces. Cal.	Energy of urine. Cal.
	Fresh. Grms.	Air-dry. Grms.								
PERIOD I:										
Steer 1,	10,664	1,742.5	69.80	74.09	4.29	23	6,784	6,807	6,231	576
Steer 2,	10,987	1,538.2	53.07	81.45	28.38	154	5,995	6,149	5,737	412
Steer 3,	12,722	1,820.5	54.62	82.50	27.88	152	7,295	7,447	7,124	323
PERIOD II:										
Steer 1,	11,985	1,935.7	74.33	82.87	8.54	47	7,040	7,087	6,469	618
Steer 2,	10,868	1,747.7	77.60	84.28	6.68	36	6,620	6,656	5,818	838
Steer 3,	12,277	2,032.0	83.52	87.46	3.94	21	7,573	7,594	6,649	945

In the above, the loss of nitrogen during drying is ascribed entirely to a decomposition of the urea of the urine. This is not strictly correct, since, as already shown, some loss of nitrogen from the feces occurred during their drying. The writer is not aware of any investigations into the nature or calorific value of these nitrogenous substances in the feces. No plausible assumption on the latter point, however, would materially alter the final result for the total energy of the excreta, but would simply result in transferring from 12 to 25 Calories from the urine to the feces.

Another possible source of error, which, so far as the writer has noticed, has never been considered in experiments of this sort, is a possible loss of non-nitrogenous matter during drying. Since we have no data on the subject, however, it must suffice here to call attention to its possibility.

The results recorded in the above table are somewhat irregular, particularly as regards the urine. This is especially the case with Nos. 2 and 3 in period I, in which there was a remarkably large loss of nitrogen during the drying and a relatively small amount of energy in the urine in proportion to its nitrogen, as the following comparison shows:

Energy per gram of Nitrogen in Urine.

	Steer 1. Cal.	Steer 2. Cal.	Steer 3. Cal.
Period I,	11.50	7.12	5.80
Period II,	10.98	14.42	16.10

Although we have no evidence of error in the analytical work, it is possible that there was a minor error in the determination of air-dry weight in these cases, resulting in too low figures for total energy. Whether this is the case or not, these two results appear abnormal and must be regarded with some suspicion.

LIVE WEIGHTS.

The daily weighings and ten-day averages as recorded in the appendix and represented on the Plates XIII, XIV and XV, show somewhat smaller fluctuations than were observed in the previous experiments. On the whole there appears to have been a slight loss of weight on the part of No. 1, and a somewhat greater gain on the part of No. 2, while No. 3 can hardly be said to have either gained or lost.

As already stated, substantially the ration of the experiment proper was fed after December 27th, 1896, and we may therefore fairly include the weighings after that date in our estimates. By the same graphic method previously employed, we obtain the following data:

Gain or Loss in Weight.

	Steer 1.	Steer 2.	Steer 3.
Weight December 27th, kgs.,	545	624	516
Weight March 27th, kgs.,	541	633	515
Gain or loss, kgs.,	—4	+9	—1
Gain or loss per day, grms.,	—44	+100	—11

Following the same methods of computation previously employed, we have the following per day and head:

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Gain or loss of nitrogen,	+0.26	—0.20	—2.31
Equivalent "flesh,"	+7.32	—5.63	—65.08
Gain or loss of weight,	—44.00	+100.00	—11.00
Computed gain or loss of fat,	—51.32	+105.63	+54.08

Estimated Production of Methan.

	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Crude fiber digested,	310.6	371.2	277.9
Nitrogen-free extract digested,	2,220.1	2,472.2	2,336.4
Total,	2,530.7	2,843.4	2,614.3
Estimated methan,	115.2	129.3	119.0
	Cal.	Cal.	Cal.
Equivalent energy,	1,525	1,714	1,575

Energy per Day and Head.

	Steer 1.		Steer 2.		Steer 3.	
	Ingesta. Cal.	Egesta. Cal.	Ingesta. Cal.	Egesta. Cal.	Ingesta. Cal.	Egesta. Cal.
Food,	20,109		21,090		21,090	
Loss from body:						
Proteids,			7		83	
Fat (estimated),	487					
Excreta:						
Feces,		6,350		5,778		6,887
Urine,		597		625		634
Methan (estimated),		1,525		1,714		1,575
Gain by body:						
Proteids,		9				
Fat (estimated),				1.002		513
For maintenance,		12.115		11.978		11.564
	20,596	20.596	21,097	21,097	21,173	21,173

Maintenance Rations per Day.

	Average live-weight. Kgs.	Energy.	
		Per head. Cal.	Per 500 kgs. live-weight. Cal.
Steer 1,	543	12,115	11,467
Steer 2,	629	11,978	10,278
Steer 3,	516	11,564	11,324

DISCUSSION OF RESULTS.

The results of the foregoing experiments, together with those summarized on previous pages, may be considered from four general points of view, viz.: 1. The digestibility of the rations; 2. The live weight as an indication of nutritive effect; 3. The energy of the food and its distribution; 4. The amount of food required for maintenance.

THE DIGESTIBILITY OF THE RATIONS.

Individual Differences in Digestive Power.

In all the experiments made here, extending over five years, the same three steers were employed, and in each experiment substantially the same ration was fed to all three simultaneously and under identical conditions as nearly as practicable. It is of some interest therefore to compare the results obtained with the different animals. The digestion coefficients obtained in the several experiments, computed in the ordinary way, without correction for metabolic products in the feces, were as follows:

Percentage Digestibility.

Material	Dry matter.	Ash.	Organic matter.	Total N x. 6.25.	Proteids.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Energy.
EXPERIMENT I. Timothy Hay.									
Steer No. 1,	57.66	40.27	58.68	48.28	44.45	51.16	65.68	51.12	54.81
Steer No. 2,	55.08	37.55	56.10	45.98	41.98	51.94	63.38	50.00	52.30
Steer No. 3,	52.71	41.18	53.38	47.51	43.63	46.31	59.25	51.12	49.69
EXPERIMENT II. Timothy Hay.									
Steer No. 1,	50.59	46.10	50.89	49.61	45.61	42.02	57.97	44.00	47.20
Steer No. 2,	58.00	48.81	58.61	55.12	51.56	51.25	64.90	53.00	55.30
Steer No. 3,	50.30	45.42	50.62	51.18	47.31	44.82	55.02	46.00	46.93
EXPERIMENT III. Timothy hay and Corn Meal.									
Steer No. 1,	51.23	17.65	52.44	55.73	54.60	4.97	71.75	61.11	47.52
Steer No. 2,	57.88	24.26	59.10	59.75	58.73	24.47	73.47	64.84	55.81
EXPERIMENT IV. Timothy Hay and Linseed Meal.									
Steer No. 1,	34.44	15.91	35.47	69.87	67.97	?	49.29	48.35	32.00
Steer No. 2,	42.11	27.73	42.92	70.00	68.11	1.31	54.06	56.04	38.90
Steer No. 3,	45.35	32.17	46.08	71.01	69.20	14.04	53.74	61.68	44.11
EXPERIMENT V. "Cotton-seed Feed."									
Steer No. 1,	42.19	19.63	42.87	35.52	....	28.30	53.36	32.86	40.83
Steer No. 2,	44.98	?	47.03	32.34	....	33.19	58.55	35.72	44.70
Steer No. 3,	42.72	24.04	43.28	40.98	....	31.92	50.09	34.00	42.66
EXPERIMENT VI. Timothy Hay.									
Steer No. 1,	58.52	49.95	59.14	56.31	53.95	57.95	61.34	45.88	55.50
Steer No. 2,	59.31	46.61	60.13	57.11	54.80	58.52	62.58	50.77	56.18
Steer No. 3	57.51	45.53	58.28	56.91	54.58	56.33	60.45	51.57	54.88
EXPERIMENT VII. Timothy Hay and Starch.									
Steer No. 1,	64.02	44.93	65.02	52.19	44.77	55.06	72.29	43.31	61.25
Steer No. 2,	63.96	46.40	64.88	49.09	41.18	54.82	72.20	51.83	60.84
Steer No. 3,	62.01	46.82	62.80	49.89	42.09	50.56	70.93	46.45	59.16

Percentage Digestibility—Continued.

Material.	Dry matter.	Ash.	Organic matter.	Total N x. 6.25.	Proteids.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Energy.
EXPERIMENT VIII. Wheat Straw, Corn Meal and Linseed Meal.									
Period I.									
Steer No. 1,	68.57	16.19	70.36	69.56	65.85	41.88	77.24	84.34	68.80
Steer No. 2,	72.84	30.63	74.24	71.40	67.92	47.84	80.77	84.21	72.61
Steer No. 3,	66.00	14.30	67.72	66.74	62.70	33.86	75.42	84.32	65.97
Period II:									
Steer No. 1,	67.81	16.90	69.53	66.09	61.80	39.46	77.52	80.26	68.06
Steer No. 2,	73.38	40.07	74.47	68.23	64.25	48.68	81.57	82.54	72.61
Steer No. 3,	68.54	24.55	69.98	65.23	60.88	33.35	78.00	83.25	68.70
AVERAGE OF ALL COEFFICIENTS.*									
Steer No. 1,	58.48	33.42	59.50	53.94	52.74	45.11	66.49	61.68	56.64
Steer No. 2,	61.08	35.72	62.21	54.18	53.62	49.46	69.14	65.44	59.22
Steer No. 3,	57.11	34.55	58.01	54.06	51.87	43.17	64.17	63.81	55.43

*Excluding Experiments III and IV.

As was pointed out in reporting them, the results of Experiments III and IV are of questionable value. Consequently, while they have been included in the table for the sake of completeness, they will not be further considered here, although so far as steers 1 and 2 are concerned they are not inconsistent with the conclusions drawn from the other experiments.

By averaging the results on each animal for the remaining seven trials, we obtain the average coefficients, given at the foot of the table. These percentages, of course, have no real significance as digestion coefficients, but are simply an expression of the average differences between the results on the three animals. A comparison of the figures shows that Steer 2 digested, on the average, markedly more of the dry matter of his food and of each single ingredient of the dry matter, than did either of the other animals. Only in the case of the total nitrogenous matter does the difference fall to an insignificant amount. In like manner, Steer No. 1 shows a distinct although less marked superiority over No. 3.

Variations from this average result will be noted in individual experiments, possibly due in part to variations in the digestion of the same feed at different times and perhaps also explicable in part by the difference in the nature of the rations. On the whole, however, there is a marked tendency to higher results with Steer 2 and to lower results with Steer 3, while Steer 1 occupies an intermediate position. This is illustrated by the following table, showing the number of times that each animal yielded the highest, the lowest or the medium result on each ingredient of the food. Thus, the first line shows that the highest result on dry matter was yielded five times by No. 2 and twice by No. 1, the medium result three times by No. 1, twice by No. 2 and twice by No. 3, and the lowest result five times by No. 3 and twice by No. 1:

	Highest.	Medium.	Lowest.
Dry matter,	1.1. 2.2.2.2.2.	1.1.1. 2.2. 3.3.	1.1. 3.3.3.3.3.
Organic matter,	1.1. 2.2.2.2.2.	1.1.1. 2.2. 3.3.	1.1. 3.3.3.3.3.
Crude fiber,	1. 2.2.2.2.2.2.2.	1.1.1.1. 3.3.	1.1. 3.3.3.3.3.
Nitrogen-free extract,	1.1. 2.2.2.2.2.	1.1.1.1. 2.2. 3.	1. 3.3.3.3.3.3.
Energy,	1.1. 2.2.2.2.2.	1.1.1. 2.2. 3.3.	1.1. 3.3.3.3.3.
Ash,	1. 2.2.2. 3.3.3.	1.1.1.1. 2.2. 3.	1.1. 2.2. 3.3.3.
Total N x. 6.25,	1.1. 2.2.2.2. 3.	1.1.1. 3.3.3.3.	1.1. 2.2.2. 3.3.
Proteids (six cases),	1.1. 2.2.2.2.	1.1. 3.3.3.3.	1.1. 2.2. 3.3.
Ether extract,	1.1.* 2.2.2. 3.3.3.*	1.* 2.2. 3.3.3.3.3.*	1.1.1.1.1. 2.2.

*Coefficients of Steers 1 and 3 identical.

From the above tabulation, we see that the highest results for the digestibility of the dry matter, organic matter, and the two most prominent constituents of the dry matter, viz., crude fiber and nitrogen-free extract, as well as for the total energy of the feed, were in most cases obtained with steer No. 2 and the lowest with steer No. 3. In no case did steer No. 2 give the lowest result, nor steer No. 3 the highest. As regards ash and ether extract, two substances present in relatively small amount and the determination of whose digestibility is attended with more or less uncertainty, no decisive results appear except that steer No. 1 appears to have had a lower digestive power for ether extract than the other animals in most cases, a conclusion substantiated by the averages of the first table. The results on total nitrogenous matter indicate but little difference between the three animals, but those on the proteids (computed on the assumption of complete digestibility of the non-proteids) seem to suggest the slight superiority on the part of steer 2 which is indicated by the average results. In the two digestion periods of Experiment VIII, the digestibility of the proteids computed in the manner described on p. 112 shows the same relations between the three animals as that found for the dry matter, viz.:

	1st Period.	2d period.
Steer No. 1,	72.14	71.57
Steer No. 2,	73.55	73.52
Steer No. 3,	71.08	69.44

and the digestibility as computed in the table above also shows the same relation.

On the whole, the above results seem to warrant the conclusion that these three animals showed specific individual differences in digestive capacity, at least for the main ingredients of the rations, No. 2 being decidedly superior to the others and No. 1 somewhat superior to No. 3. This is also the order of their live weights, but we are hardly safe in regarding this as more than a coincidence. The averages for dry matter on p. 126 show a difference of 2.6 per cent. between No. 2 and No. 1 and of 1.37 per cent. between No. 1 and No. 3, but it seems questionable whether much significance attaches to this numercial expression of the differences except as showing that they are not greater than those which have been observed by other experimenters.

It is perhaps worth noting, however, that the results in Experiment VI, covering 56 days and in which the possible error due to variations in digestibility may be assumed to have been practically eliminated, fully confirm the conclusion drawn from the shorter periods of the remaining experiments.

Variations in Digestibility.

It has been shown by G. Kühn* that the digestibility of the same ration by the same animal may vary at different times.

In the experiments of 1894-5, the consumption and excretion of air-dry matter and nitrogen were determined daily for two periods of 79 and 49 days respectively, and during a large portion of each of these periods the ration was as nearly uniform as it was practicable to make it. It is a matter of some interest, therefore, to follow the digestibility of these rations throughout these comparatively long periods.

The average digestibility of air dry-matter and nitrogen during the two periods of uniform feeding has already been computed (pp. 79 and 93) with the following results:

Percentage Digestibility.

	Air-dry matter.	Total nitrogen.
EXPERIMENT VI: DECEMBER 20-FEBRUARY 13. 56 days.		
Steer No. 1,	58.30	56.31
Steer No. 2,	59.48	57.11
Steer No. 3,	57.31	56.91
EXPERIMENT VII: MARCH 28-APRIL 23. 27 days.		
Steer No. 1,	64.02	52.19
Steer No. 2,	63.53	49.09
Steer No. 3,	61.89	49.89

In view of the length of the periods covered, the above results, particularly those of Experiment VI, on exclusive hay feeding, may be safely regarded as representing the average digestibility of the rations. Assuming this to be the case, we may test the question of a possible variation in digestibility in two ways. First, we can, by the use of the above co-efficients compute the amounts of *indigestible* air-dry matter and nitrogen contained in the daily ration and compare them with the actual amounts excreted in the feces; or, second. we may compute the percentage digestibility in successive sub-periods and compare the co-efficients thus obtained with each other and with the averages given above. The latter method is at first sight the more direct and obvious one, but both afford results of some interest.

In either case, it is obviously necessary to make the comparisons between the averages of a number of days in order to eliminate the effect of the considerable daily variations in excretion. For this purpose, a ten-day period has been used and the averages calculated for overlapping periods exactly in the same manner as in case of the live weights. Thus, the average for the first ten days has been entered in the tables and plotted on the plate upon the fifth day, the average of the second to the eleventh days inclusive on the sixth day; that for the third to the twelfth days, inclusive, opposite the seventh day, and so on.

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*Landw. Vers. Stat., 29, 129-135.

COMPUTED INDIGESTIBLE MATTER.

The following table contains the ten-day averages, computed in the manner just explained, for the air-dry matter and nitrogen of the food, and also shows the amounts of indigestible air-dry matter and nitrogen computed to have been contained in them, using the average co-efficients on p. 129. If the digestibility was uniformly that shown by these co-efficients, these amounts should, of course, correspond to the air-dry matter and nitrogen found in the feces.

The portion of the experiment extending from March 14 to Mar. 27, inclusive, constituted a transition period from the exclusive hay feeding to the final ration of hay and starch. For those ten-day averages which cover any portion of this transition period, the indigestible matter has been estimated on the assumption of complete digestibility of the starch, using the co-efficients given above for the hay fed alone (March 5-13 inclusive), and those given on page 93 for the hay fed along with starch.

	Eaten.		Computed Indigestible.					
			Air-dry Matter.			Nitrogen.		
	Air-dry matter. Grms.	Nitrogen. Grms.	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Nov. 28-Dec. 7, 1894, ...	5,855	95.44	....	....	....	....	....	....
Nov. 29-Dec. 8, 1894, ...	5,855	95.44	....	....	....	....	....	....
Nov. 30-Dec. 9, 1894, ...	5,855	95.44	....	....	....	....	....	....
Dec. 1-10, 1894, ...	5,855	95.44	....	....	....	....	....	....
Dec. 2-11, 1894, ...	5,855	95.44	....	....	....	....	....	....
Dec. 3-12, 1894, ...	5,855	95.44	....	....	....	....	....	....
Dec. 4-13, 1894, ...	5,846	94.45	....	....	....	....	....	....
Dec. 5-14, 1894, ...	5,836	93.46	....	....	....	....	....	....
Dec. 6-15, 1894, ...	5,827	92.47	....	....	....	....	....	....
Dec. 7-16, 1894, ...	5,817	91.48	....	....	....	....	....	....
Dec. 8-17, 1894, ...	5,808	90.49	....	....	....	....	....	....
Dec. 9-18, 1894, ...	5,798	89.50	....	....	....	....	....	....
Dec. 10-19, 1894, ...	5,789	88.51	....	....	....	....	....	....
Dec. 11-20, 1894, ...	5,794	87.29	....	....	....	....	....	....
Dec. 12-21, 1894, ...	5,799	86.08	....	....	....	....	....	....
Dec. 13-22, 1894, ...	5,804	84.86	2,420	2,352	2,478	37.07	36.40	36.57
Dec. 14-23, 1894, ...	5,818	84.63	2,426	2,358	2,484	36.98	36.30	36.47
Dec. 15-24, 1894, ...	5,833	84.41	2,432	2,364	2,490	36.88	36.20	36.37
Dec. 16-25, 1894, ...	5,847	84.18	2,438	2,369	2,496	36.78	36.11	36.27
Dec. 17-26, 1894, ...	5,862	83.95	2,447	2,375	2,502	36.68	36.01	36.18
Dec. 18-27, 1894, ...	5,886	83.68	2,455	2,385	2,513	36.56	35.89	36.06
Dec. 19-28, 1894, ...	5,910	83.41	2,465	2,395	2,523	36.44	35.78	35.94
Dec. 20-29, 1894, ...	5,934	83.14	2,475	2,406	2,533	36.32	35.66	35.82
Dec. 21-30, 1894, ...	5,943	83.09	2,478	2,408	2,537	36.30	35.64	35.80
Dec. 22-31, 1894, ...	5,953	83.05	2,483	2,412	2,541	36.29	35.62	35.79
Dec. 23-Jan. 1, 1895, ...	5,963	83.00	2,487	2,416	2,546	36.26	35.60	35.76
Dec. 24-Jan. 2, 1895, ...	5,972	82.96	2,490	2,420	2,549	36.25	35.58	35.75
Dec. 25-Jan. 3, 1895, ...	5,970	83.19	2,490	2,419	2,549	36.35	35.68	35.85
Dec. 26-Jan. 4, 1895, ...	5,968	83.43	2,489	2,418	2,548	36.45	35.79	35.96
Dec. 27-Jan. 5, 1895, ...	5,967	83.67	2,488	2,418	2,547	36.56	35.89	36.05
Dec. 28-Jan. 6, 1895, ...	5,955	83.95	2,483	2,413	2,542	36.68	36.01	36.17
Dec. 29-Jan. 7, 1895, ...	5,944	84.24	2,479	2,409	2,538	36.80	36.13	36.30
Dec. 30-Jan. 8, 1895, ...	5,932	84.52	2,474	2,404	2,532	36.93	36.26	36.42
Dec. 31-Jan. 9, 1895, ...	5,921	84.80	2,469	2,399	2,528	37.05	36.37	36.54
Jan. 1-10, 1895, ...	5,909	84.79	2,464	2,394	2,523	37.04	36.37	36.54
Jan. 2-11, 1895, ...	5,898	84.78	2,460	2,390	2,518	37.04	36.36	36.53
Jan. 3-12, 1895, ...	5,886	84.77	2,455	2,385	2,513	37.04	36.36	36.53
Jan. 4-13, 1895, ...	5,886	84.47	2,455	2,385	2,513	36.91	36.23	36.40
Jan. 5-14, 1895, ...	5,886	84.18	2,455	2,385	2,513	36.78	36.11	36.27
Jan. 6-15, 1895, ...	5,886	83.88	2,455	2,385	2,513	36.65	35.98	36.14
Jan. 7-16, 1895, ...	5,886	83.59	2,455	2,385	2,513	36.52	35.8[illegible]	36.02
Jan. 8-17, 1895, ...	5,843	83.04	2,437	2,368	2,494	36.28	35.62	35.78
Jan. 9-18, 1895, ...	5,800	82.49	2,419	2,350	2,476	36.04	35.38	35.54
Jan. 10-19, 1895, ...	5,757	81.95	2,401	2,333	2,458	35.80	35.15	35.32
Jan. 11-20, 1895, ...	5,714	81.70	2,383	2,315	2,439	35.69	35.04	35.20

	Eaten.		Computed Indigestible.					
			Air-dry Matter.			Nitrogen.		
	Air-dry matter. Grms.	Nitrogen. Grms.	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.	Steer 1. Grms.	Steer 2. Grms.	Steer 3. Grms.
Jan. 12-21, 1895,	5,671	81.45	2,365	2,298	2,421	35.59	34.93	35.09
Jan. 13-22, 1895,	5,627	81.19	2,347	2,280	2,402	35.47	34.82	34.98
Jan. 14-23, 1895,	5,584	80.94	2,329	2,263	2,384	35.36	34.71	34.88
Jan. 15-24, 1895,	5,567	81.09	2,322	2,256	2,377	35.43	34.78	34.94
Jan. 16-25, 1895,	5,549	81.25	2,314	2,248	2,369	35.50	34.85	35.01
Jan. 17-26, 1895,	5,531	81.40	2,307	2,241	2,361	35.56	34.91	35.07
Jan. 18-27, 1895,	5,557	81.80	2,317	2,252	2,372	35.74	35.08	35.25
Jan. 19-28, 1895,	5,582	82.20	2,328	2,262	2,383	35.91	35.26	35.42
Jan. 20-29, 1895,	5,607	82.60	2,338	2,272	2,394	36.09	35.43	35.59
Jan. 1-30, 1895,	5,633	83.00	2,349	2,283	2,405	36.26	35.60	35.76
Jan. 22-31, 1895,	5,673	82.99	2,367	2,299	2,422	36.26	35.59	35.76
Jan. 23-Feb. 1, 1895,	5,714	82.97	2,383	2,315	2,439	36.25	35.59	35.75
Jan. 24-Feb. 2, 1895,	5,755	82.95	2,400	2,332	2,457	36.24	35.58	35.74
Jan. 25-Feb. 3, 1895,	5,770	82.53	2,406	2,338	2,463	36.06	35.40	35.56
Jan. 26-Feb. 4, 1895,	5,785	82.11	2,412	2,344	2,470	35.87	35.22	35.38
Jan. 27-Feb. 5, 1895,	5,800	81.68	2,419	2,350	2,476	35.69	35.03	35.19
Jan. 28-Feb. 6, 1895,	5,815	81.26	2,425	2,356	2,482	35.50	34.85	35.01
Jan. 29-Feb. 7, 1895,	5,827	81.73	2,430	2,361	2,488	35.71	35.05	35.22
Jan. 30-Feb. 8, 1895,	5,839	82.20	2,435	2,366	2,493	35.91	35.26	35.42
Jan. 31-Feb. 9, 1895,	5,851	82.67	2,440	2,371	2,498	36.12	35.46	35.62
Feb. 1-10, 1895,	5,848	83.56	2,439	2,370	2,496	36.51	35.84	36.01
Feb. 2-11, 1895,	5,845	84.45	2,438	2,368	2,495	36.90	36.22	36.39
Feb. 3-12, 1895,	5,842	85.34	2,436	2,367	2,494	37.28	36.60	36.77
Feb. 4-13, 1895,	5,839	86.23	2,435	2,366	2,493	37.67	36.99	37.16
Feb. 5-14, 1895,	5,829	87.13	2,431	2,362	2,488	38.07	37.37	37.54
Feb. 6-15, 1895,	5,818	88.03	2,426	2,357	2,484	38.46	37.76	37.93
March 5-14, 1895,	5,541	80.34	2,311	2,245	2,365	35.10	34.46	34.62
March 6-15, 1895,	5,563	80.44	2,320	2,254	2,375	35.14	34.50	34.66
March 7-16, 1895,	5,585	80.53	2,329	2,263	2,384	35.18	34.54	34.70
March 8-17, 1895,	5,618	80.95	2,343	2,276	2,398	35.37	34.72	34.88
March 9-18, 1895,	5,652	81.37	2,357	2,290	2,413	35.55	34.90	35.06
March 10-19, 1895,	5,685	81.79	2,372	2,304	2,427	35.73	35.08	35.24
March 11-20, 1895,	5,718	82.21	2,385	2,317	2,441	35.92	35.26	35.43
March 12-21, 1895,	5,701	80.69	2,355	2,387	2,528	38.58	41.08	40.44
March 13-22, 1895,	5,684	79.16	2,311	2,345	2,483	37.85	40.30	39.67
March 14-23, 1895,	5,667	77.64	2,272	2,303	2,439	37.12	39.53	38.91
March 15-24, 1895,	5,617	75.69	2,218	2,248	2,371	36.19	38.53	37.93
March 16-25, 1895,	5,567	73.75	2,162	2,192	2,320	35.26	37.55	36.96
March 17-26, 1895,	5,517	71.80	2,107	2,136	2,261	34.33	36.55	35.98
March 18-27, 1895,	5,467	69.86	2,052	2,080	2,202	33.40	35.57	35.01
March 19-28, 1895,	5,448	67.45	2,010	2,037	2,158	32.25	34.34	33.80
March 20-29, 1895,	5,429	65.05	1,969	1,996	2,113	31.10	33.12	32.60
March 21-30, 1895,	5,410	62.65	1,928	1,954	2,068	29.95	31.90	31.40
March 22-31, 1895,	5,441	62.19	1,941	1,967	2,083	29.73	31.66	31.17
March 23-April 1, 1895,	5,472	61.73	1,955	1,981	2,098	29.51	31.43	30.94
March 24-April 2, 1895,	5,502	61.27	1,968	1,995	2,112	29.29	31.19	30.70
March 25-April 3, 1895,	5,533	60.81	1,981	2,009	2,127	29.07	30.96	30.47
March 26-April 4, 1895,	5,575	59.52	2,000	2,027	2,146	28.46	30.30	29.83
March 27-April 5, 1895,	5,616	58.23	2,018	2,045	2,165	27.84	29.65	29.18
March 28-April 6, 1895,	5,657	56.93	2,035	2,063	2,184	27.22	28.98	28.53
March 29-April 7, 1895,	5,667	56.10	2,039	2,067	2,188	26.82	28.56	28.11
March 30-April 8, 1895,	5,678	55.26	2,043	2,071	2,192	26.42	28.13	27.69
March 31-April 9, 1895,	5,688	54.42	2,047	2,074	2,196	26.02	27.71	27.27
April 1-10, 1895,	5,698	53.59	2,050	2,078	2,200	25.62	27.28	26.86
April 2-11, 1895,	5,702	54.20	2,052	2,080	2,202	25.91	27.59	27.16
April 3-12, 1895,	5,705	54.81	2,053	2,081	2,203	26.20	27.91	27.47
April 4-13, 1895,	5,709	55.42	2,054	2,082	2,204	26.50	28.22	27.77
April 5-14, 1895,	5,702	56.87	2,052	2,080	2,202	27.19	28.95	28.50
April 6-15, 1895,	5,696	58.32	2,049	2,077	2,199	27.88	29.69	29.23
April 7-16, 1895,	5,682	58.95	2,044	2,072	2,194	28.18	30.01	29.54
April 8-17, 1895,	5,668	59.78	2,039	2,067	2,188	28.48	30.33	29.86
April 9-18, 1895,	5,654	60.21	2,034	2,062	2,183	28.79	30.65	30.17
April 10-19, 1895,	5,640	60.84	2,029	2,057	2,178	29.09	30.97	30.49
April 11-20, 1895,	5,626	61.48	2,024	2,052	2,172	29.39	31.30	30.81
April 12-21, 1895,	5,618	60.66	2,021	2,049	2,169	29.00	30.88	30.40
April 13-22, 1895,	5,611	59.84	2,019	2,046	2,166	28.62	30.47	29.99
April 14-23, 1895,	5,604	59.02	2,016	2,044	2,164	28.22	30.05	29.58

In comparing the amounts of computed indigestible matter contained in the above table with the amounts actually excreted, it appears questionable whether the comparison should be made with the excretion of the same days or, as is more probably the case, with that of a few days later. In order to get some light upon this point, the results contained in the above table, together with the ten day averages for the amounts of air dry matter and nitrogen actually excreted, were plotted upon cross-section paper. By taking off one of the resulting curves on tracing paper and placing it over the other, it was easy to compare the two. Obviously, if there were no variations in digestibility or in rate of excretion of the feces, there should be some position in which these curves correspond. As a matter of fact, however, such a coincidence was by no means found. The following are the general results of the comparison:

Air-dry Matter.

Steer 1. Experiment VI.—The closest correspondence is obtained by comparing the observed amounts excreted with those computed from the food of the third day before. There appears to be a gradual falling off in digestibility (increase of feces) as compared with the average. The greatest difference between the computed and observed amounts compared as above is about 100 grams.

Experiment VII.—Corresponds quite closely, when compared as above, for that portion of the period covered by actual results.

Steer 2. Experiment VI.—The observed amounts are quite irregular and do not correspond well with the computed amounts. The correspondence is as close when compared as in case of Steer 1 as on any other basis but differences of 150 to 200 grams are not uncommon.

Experiment VII.—A fairly good correspondence, either on the above basis or comparing observed and computed for the same days, for that portion of the experiment for which actual results are available.

Steer 3. Experiment VI.—The closest correspondence is obtained by comparing the observed amounts with the computed amounts for the same days. If the comparison is made on the same basis as in the case of Steer 1, Experiment VI, the correspondence is less close, but still good, the greatest difference not being over 100 grams.

Nitrogen.

An error in sampling the hay appears to have been committed in Experiment VII, the sample for April 4-10 being exceptioinally low in nitrogen and that for April 11-15 exceptionally high, while neither feces nor urine show any corresponding fluctuation. The comparisons for observed and computed nitrogen for this period are therefore of little value and are omitted here.

Steer 1. Experiment VI.—The same relation holds as for the air-dry matter, except a rather wide variation for the averages of Jan. 3d to Feb. 7th, inclusive. The observed amount here is greater than the computed by over two grams, while for the remainder of the period the differences do not rise to much over one gram.

Steer 2. Experiment VI.—As under air-dry matter. An exceptionally large difference Jan. 27th and on last three days, amounting to over 2 grams. Other differences 1 to 1.5 grams.

Steer 3. Experiment VI.—The observed amounts, compared with the computed amounts of three days previous, are usually higher except from January 16th to 23-24, when they are decidedly lower. The general course of the two is closely parellel, except for this period, the observed amount being about 0.75 grams, above the computed, the difference rising occasionally to 1 to 1.5 grams.

On the whole, taking into account our knowledge of the time required for the passage of the food through the alimentary canal of herbivora, the above results seem to indicate that a fair basis for computing digestibility is a comparison of the feces with the food eaten about three days before, and in Plate XVI the observed and computed indigestible matter of the hay is compared on this basis.

PERCENTAGE DIGESTIBILITY.

The second, and for some purposes more satisfactory, view of these differences is obtained if we compute on the above basis the percentage digestibility of the ration from the results of the over-lapping ten-day periods. In this way, the variations between computed and actual indigestible matter are translated into variations in the apparent digestibility of the food and we secure in this way an idea of the degree to which the results of an ordinary ten-day digestion trial may vary from the truth. The following table contains the results of such a computation covering the whole time during which the excreta were collected, the date given being that on which the food was eaten.

Percentage Digestibility.

Date.	Steer 1.		Steer 2.		Steer 3.	
	Air-dry matter.	Nitrogen.	Air-dry matter.	Nitrogen.	Air-dry matter.	Nitrogen.
November 25-December 4,	52.88	52.10	56.39	54.34	53.22	53.32
November 26-December 5,	53.07	54.18	56.39	54.37	54.41	55.42
November 27-December 6,	52.88	54.63	56.91	55.51	55.11	55.93
November 28-December 7,	53.82	55.97	57.74	56.88	55.95	57.36
Nocember 29-December 8,	54.01	56.77	57.93	57.86	57.16	59.13
November 30-December 9,	54.18	57.47	56.92	57.38	57.83	60.01
December 1-10,	55.13	58.28	58.12	58.58	57.79	59.90
December 2-11,	56.12	59.14	58.65	59.01	56.96	59.02
December 3-12,	57.11	60.04	57.13	57.43	57.14	59.49
December 4-13,	57.39	60.05	58.43	58.55	57.11	59.22
December 5-14,	57.81	60.28	57.71	58.80	57.19	59.17
December 6-15,	57.58	59.64	57.30	58.45	56.61	58.22
December 7-16,	58.36	60.06	57.59	58.11	57.21	59.21
December 8-17,	58.19	59.89	57.35	57.43	57.14	58.73
December 9-18,	58.47	59.84	57.67	57.24	56.40	57.60
December 10-19,	59.42	60.35	58.78	57.91	55.81	56.68
December 11-20,	58.94	59.30	56.93	55.59	55.35	55.81
December 12-21,	58.54	58.41	58.16	56.37	55.90	55.87
December 13-22,	58.96	58.20	58.87	56.41	56.10	55.38
December 14-23,	59.23	58.18	58.61	55.72	56.49	56.05
December 15-24,	59.02	57.71	59.40	56.43	56.26	55.62
December 16-25,	59.10	57.70	59.83	56.59	56.71	55.74
December 17-26,	58.72	56.80	59.57	56.22	56.73	55.28
December 18-27,	59.04	56.80	59.38	55.81	56.68	55.20
December 19-28,	59.56	56.39	58.83	55.04	57.33	55.34
December 20-29,	59.03	55.22	59.18	55.29	57.83	55.47
December 21-30,	58.96	56.29	59.58	55.77	58.39	56.07

Percentage Digestibility—Continued.

Date.	Steer 1.		Steer 2.		Steer 3.	
	Air-dry matter.	Nitrogen.	Air-dry matter.	Nitrogen.	Air-dry matter.	Nitrogen.
December 22-31,	59.52	57.13	59.45	55.61	58.27	55.71
December 23-January 1,	59.23	56.72	59.36	55.49	58.18	55.73
December 24-January 2,	59.96	57.46	59.93	55.94	57.45	54.88
December 25-January 3,	59.56	57.08	59.91	55.92	57.62	55.47
December 26-January 4,	59.55	57.13	59.58	55.90	57.78	55.78
December 27-January 5,	59.73	57.44	60.25	56.58	58.42	56.56
December 28-January 6,	59.50	57.70	61.71	58.29	57.83	56.41
December 29-January 7,	58.58	56.97	62.25	59.32	57.23	55.55
December 30-January 8,	58.48	56.85	60.84	57.75	57.01	55.82
December 31-January 9,	58.39	56.85	61.81	59.08	56.96	55.80
January 1-10,	57.81	56.35	60.40	57.99	57.24	56.29
January 2-11,	57.75	56.20	61.00	58.67	56.96	56.04
January 3-12,	57.00	55.33	60.09	58.00	57.20	56.56
January 4-13,	57.87	56.07	59.90	57.75	57.35	56.86
January 5-14,	57.69	55.54	59.72	57.52	57.18	56.71
January 6-15,	57.53	55.19	59.35	57.15	57.00	56.51
January 7-16,	57.83	55.21	58.17	55.92	57.35	56.64
January 8-17,	57.88	55.43	58.10	55.74	57.69	57.67
January 9-18,	57.93	55.65	59.69	57.82	58.41	58.59
January 10-19,	57.96	55.69	59.23	57.28	58.12	58.58
January 11-20,	58.00	55.78	59.26	57.24	58.33	58.88
January 12-21,	58.19	56.06	58.24	56.52	58.56	59.32
January 13-22,	58.28	56.46	58.11	56.49	58.75	59.22
January 14-23,	58.24	56.45	57.97	56.53	58.43	58.65
January 15-24,	58.29	56.71	57.69	56.45	58.29	58.71
January 16-25,	58.17	56.62	57.72	56.91	57.83	58.37
January 17-26,	57.51	56.03	57.42	56.90	57.49	58.39
January 18-27,	58.23	56.52	57.01	56.15	57.15	58.03
January 19-28,	57.32	55.63	56.12	54.90	56.46	57.30
January 20-29,	58.03	56.03	55.61	54.25	56.82	57.14
January 21-30,	58.40	56.50	56.70	55.48	55.60	56.27
January 22-31,	57.46	55.27	56.44	54.80	55.86	56.04
January 23-February 1,	56.82	54.26	57.19	55.22	56.07	56.81
January 24-February 2,	56.82	53.97	57.79	55.62	55.03	55.93
January 24-February 3,	56.29	53.58	59.20	56.57	55.63	56.27
January 26-February 4,	56.61	53.61	59.05	55.84	56.23	56.67
January 27-February 5,	56.88	53.54	59.46	55.83	56.27	55.80
January 28-February 6,	57.07	53.05	59.81	55.88	56.28	56.13
January 29-February 7,	57.03	53.41	60.75	57.38	56.45	55.57
January 30-February 8,	57.32	54.19	60.28	57.47	57.02	56.62
January 31-February 9,	57.24	54.30	60.83	58.22	57.63	57.49
February 1-10,	57.81	55.59	62.38	60.40	57.59	57.86
February 2-11,	57.00	55.43	61.74	60.09	58.08	57.96
February 3-12,	57.03	56.07	60.46	59.32	58.79	58.62
March 3-12,	55.79	55.20	59.36	57.13	57.64	56.20
March 4-13,	55.74	54.63	59.31	56.79	57.56	56.23
March 5-14,	57.30	55.72	58.38	55.71	57.73	56.33
March 6-15,	58.13	56.61	58.44	55.49	58.87	56.93
March 7-16,	58.96	57.29	60.21	57.32	59.82	57.53
March 8-17,	60.09	58.35	61.64	58.52	60.86	58.16
March 9-18,	60.53	59.06	61.99	58.86	61.62	59.01
March 10-19,	61.16	59.73	62.25	59.16	62.83	60.46
March 11-20,	61.72	60.30	62.63	59.56	64.36	62.22
March 12-21,	62.20	59.91	63.18	59.46	64.57	61.79
March 13-22,	62.67	59.63	63.17	58.78	65.50	62.04
March 14-23,	64.14	60.37	63.88	59.02	66.01	62.01
March 15-24,	63.82	59.30	65.64	60.31	65.46	60.99
March 16-25,	63.71	58.17	65.29	59.32	64.85	59.90
March 17-26,	63.04	56.64	64.74	57.98	63.93	58.64
March 18-27,	62.48	55.69	63.38	55.97	63.30	57.93
March 19-28,	62.61	54.85	64.03	55.73	62.79	56.56
March 20-29,	62.99	53.95	64.60	55.49	61.68	54.29
March 21-30,	63.20	53.01	63.88	53.05	61.38	52.85
March 22-31,	63.94	53.88	63.33	52.01	61.71	53.06
March 23-April 1,	63.87	53.91	63.85	52.47	60.83	51.87
March 24-April 2,	63.32	53.53	63.68	52.13	60.49	51.49
March 25-April 3,	63.35	53.64	62.39	50.32	60.62	51.42
March 26-April 4,	63.19	52.60	62.62	49.58	60.95	51.01
March 27-April 5,	63.85	52.48	62.96	49.04	61.02	49.84
March 28-April 6,	64.17	51.32	63.78	48.92	61.13	48.42
March 29-April 7,	64.27	50.62	64.02	46.04	61.18	47.62
March 30-April ,8	63.86	49.71	61.64	44.03	61.48	47.57
March 31-April 9,	64.28	49.70	62.61	45.12	61.39	46.84
April 1-10,	64.04	48.22	63.00	44.91	61.56	45.96
April 2-11,	64.26	48.56	62.19	44.44	61.96	46.58
April 3-12,	65.10	49.77	62.80	45.42	62.49	47.80
April 4-13,	64.51	49.20	63.30	46.33	62.23	48.25
April 5-14,	64.05	50.48	63.83	48.71	61.84	49.50
April 6-15,	64.55	52.64	62.73	48.61	62.57	51.88
April 7-16,	64.27	53.45	62.97	49.65	62.02	52.22
April 8-17,	63.80	53.71	64.32	52.06	61.80	52.68
April 9-18,	63.85	54.32	65.08	53.66	61.56	52.91
April 10-19,	63.33	54.71	64.31	53.19	61.31	53.12
April 11-20,	61.62	55.84	64.18	53.06	60.47	53.04

The above results are represented graphically by red lines in plate XVII, while the broken black lines represent the averages for the whole experiment.

PROBABLE ERRORS.

It is apparent from the figures of the preceding table as well as from the plate that there was considerable apparent fluctuation in the digestibility of the ration at different times. Before we can discuss this variation, however, it is necessary to secure some definite knowledge as to the amount of experimental error involved. The following computations are an attempt to secure such data. While the methods and formulæ for the computation of probable error have been used, even a cursory examination of the results will suffice to show that these computations are by no means of rigid mathematical accuracy. At the same time, it is believed that they may serve their purpose of giving at least a fairly approximate idea of the probable limits of experimental error.

Errors in Weighing.—The food and excreta were weighed on a Fairbanks "silk scales" weighing to 7 grams. No direct determinations of the probable error of weighing were made, but it is believed that it was certainly not greater than 7 grams. This is equivalent to 0.115 per cent. of the total weight in the case of the food and to one-half as much in the case of the feces. These errors are very small as compared with others and since they would not materially affect the results they have not been included in the subsequent calculations.

Errors in Determination of Air-dry Matter of Feces.—During the greater part of the experiment 1-100 of the amount excreted daily, weighed to the nearest whole gram, was taken for air-drying and the air-dry residue was also weighed to the nearest gram. Beginning on February 4th, 200 grams were taken daily for air-drying and about the last of February the amount was increased to 300 grams. The weighing simply to the nearest whole gram involves a certain amount of error. To get an approximate idea of its amount 12 tin boxes partly filled with dry sand were weighed on a balance sensitive to 1-100 gram, the weights having about the range of the amounts of feces weighed out for air-drying. The same number of porcelain crucibles containing dry sand were weighed to 1-100 gram on a chemical balance, each one being made to weigh 20 per cent. of the corresponding tin box, this being about the average percentage of air-dry matter found in the feces. These two sets of boxes were then weighed on the balance used in the determination of air-dry matter exactly as if they had been samples under treatment. The results of these two sets of weighings are given in the following table:

No.	Correct Weights.		Weights on Large Balance.		B÷A Per cent.	Error. Per cent.
	a.	b.	A.	B.		
1, ...	102.95	20.59	103	21	20.39	+0.39
2, ...	99.09	19.82	99	20	20.20	+0.20
2, ...	116.06	23.21	117	23	19.66	-0.34
4, ...	141.60	28.32	142	29	20.42	+0.42
5, ...	123.67	24.73	124	25	20.17	+0.17
6, ...	114.37	22.87	114	23	20.18	+0.18
7, ...	126.33	25.27	126	25	19.84	-0.16
8, ...	145.17	29.03	145	29	20.	0.
9, ...	110.67	22.13	110	22	20.	0.
10, ...	122.20	24.44	122	24	19.67	-0.33
11, ...	123.90	24.78	124	25	20.17	+0.17
12, ...	104.92	20.98	105	21	20.	0.

This gives as the probable error of one determination ±0.1629 per cent, equivalent, in round numbers, to ±0.8 per cent of the amount determined.

A further source of error in this connection is due to possible variations in the amounts of moisture remaining in the air-dry samples, the computations of digestibility above made, of course, being based upon the assumption that the amount of moisture remaining in the samples was uniform. All the air-dryings were made in the same steam-drying closet, at a temperature of approximately 60 degrees Centigrade and the air-dried samples were exposed for two or three days at ordinary temperature before being weighed. Differences in the hygroscopic moisture of the different samples, therefore, were likely to be due chiefly to differences in the relative humidity of the air of the laboratory. As a check upon the differences likely to occur, we may use the following list of the percentages of hygroscopic moisture found in samples of steer and cow feces from previous digestion experiments. All of these samples were dried in the same drying closet as those under consideration and all during the winter and early spring months.

Kind of Feed.	Kind of animal.	Moisture in air-dry feces. Per cent.
Corn silage, ...	Steers, ...	6.34 6.16 8.53 7.28
Corn forage, ...	Steers, ...	8.56 8.40
Timothy hay, ...	Steers, ...	4.38 4.01 4.03 5.01 4.77 4.98
Timothy hay and corn meal, ...	Steers, ...	2.60 3.68 3.34
Timothy hay and linseed meal, ...	Steers, ...	4.71 4.54 4.73

Kind of feed.	Kind of animal.	Moisture in air-dry feces. Per cent.
Cotton-seed feed,	Steers,	5.67
		5.25
		4.84
Mixed hay, corn stover, corn meal, cotton-seed meal,	Cows,	5.67
		5.33
		5.07
		3.68
		3.42
		3.42
		4.00
		4.12
		4.08
		3.61
		4.15
		4.67
		4.32
		4.45
Corn stover, ground wheat, gluten meal, cotton-seed meal or linseed meal,	Cows,	6.14
		6.48
		5.29
		4.99
		7.53
		7.63
		6.09
		5.78
Timothy hay,	Steers,	7.08
		6.25
		5.91
		5.75
		6.07
		5.80
		6.30

While the variations of the individual figures in the above table from the average cannot be regarded as errors in the strict sense of the term, they do show the variations from average moisture content likely to occur in any single sample, and if we treat them as errors and apply the formula for probable error, we shall have a result which will indicate, approximately at least, how much any single determination of air-dry matter is likely to depart from the average. The result of this computation gives as the probable variation of a single determination, in round numbers, 0.9 per cent. of the amount determined.

The total probable error of a single determination of air-dry matter excreted, then, will be made up of the probable error in weighing and the probable variation from the average percentage of moisture in the air-dry matter. Combining these, we have as the total probable error

$$\pm\sqrt{0.8^2+0.9^2}=\pm1.2\%$$

of the amount determined.

Error in Determination of Air-dry Matter of Hay.—The air-drying of the hay was made in the same manner as that of the feces, but upon a thousand gram sample in every case. We may therefore assume for our present purpose, without material error, that the probable error of weighing was one-tenth of that for the feces, namely .08 per cent. of the amount determined. In the lack of sufficient data for a direct comparison of the variations of moisture in the air-dry samples, we may assume that it would not be greater than that found for the feces. On this basis the probable error of a single determination of air-dry matter in hay would be

$$\pm\sqrt{0.9^2+0.08^2}=\pm 0.9036$$

or practically ±0.9 per cent.

Probable Error of Nitrogen Determination —On Dec 3d, twelve different samples of the feces of Steer 3 were taken and separately analyzed as a test of the accuracy of the method of sampling and likewise of the probable errors in the determination of nitrogen and dry matter. The sampling was done by spreading the material on a cement floor, chopping and mixing it with a shovel, and taking several portions from different parts of the mass with the point of a mason's trowel. The results of the determinations of dry matter and nitrogen were as follows:

Sample No.	Loss in air-drying. Per cent.	Water in air-dry material. Per cent.	Nitrogen in air-dry material. Per cent.	As Sampled.	
				Dry matter. Per cent.	Nitrogen. Per cent.
17185,	80.	7.28	1.57	18.64	0.314
17186,	80.	7.02	1.56	18.60	0.310
17187,	80.	7.16	1.57	18.57	0.314
17188,	80.	7.15	1.57	18.57	0.314
17189,	80.	7.14	1.565	18.57	0.313
17190,	80.	7.03	1.56	18.59	0.312
17191,	80.	7.34	1.56	18.63	0.312
17192,	80.	6.98	1.545	18.60	0.309
17193,	80.83	6.82	1.535	17.85	0.294
17194,	80.83	7.03	1.545	17.81	0.296
17195,	80.	6.97	1.545	18.61	0.309
17196,	80.	7.08	1.52	18.58	0,304
Average,	80.14	7.083	....	18.45	0.3084
Probable error of one determination,	....	....	....	0.187	0.0044
Percentage error,	....	....	....	1.01	1.43

The probable error, as computed above, for the dry matter and nitrogen includes all the errors due to sampling and irregularity of drying and to analytical errors. Similar determinations were not made on samples of hay, but we may perhaps assume the probable error in this case to have been at least no greater.

Probable Errors of Co-efficients.—In the case of the average coefficients for the period from Dec. 20 to Feb. 13th, inclusive, the probable errors on the above basis are computed as follows. During this time, there were taken eight samples of hay and fifty-one samples of feces. The percentage errors, then, will be those given above divided by the square root of the number of samples.

Probable errors of Hay.

Nitrogen, ... $1.4 \div \sqrt{8}$—.494%

Air-dry matter, ... $0.9 \div \sqrt{8}$—.318%

Probable errors of Feces.

Nitrogen, ... $1.4 \div \sqrt{51}$—.196%

Air-dry matter, ... $1.2 \div \sqrt{51}$—.168%

Since the computed error will be substantially the same for all three animals, we may limit our computations to a single one.

The figures for Steer 1 would be as follows:

	Air-dry matter. Grms.	Nitrogen. Grms.
Eaten,	325,724±1036	4674.18±23.12
Excreted,	135,820± 228	2042.15± 4.00
Digested,	189,904±1060	2632.03±23.47
Per cent. digested,	58.30±0.33	56.3± 0.50

For the co-efficients computed from the ten-day averages, each representing two samples of hay and ten samples of feces, the probable errors would be as follows, taking the figures for the average daily food-consumption and excretion of Steer 1 as a basis for the comparison.

Probable errors of Hay.

Nitrogen, ... $1.4 - \sqrt{\ }$=0.99%

Air-dry matter, ... $0.9 \div \sqrt{2}$— .636%

Probable errors of Feces.

Nitrogen, ... $1.4 \div \sqrt{10}$—0.446%

Air-dry matter, ... $1.2 \div \sqrt{10}$— 3795%

Average per Day for Steer 1.

	Air-dry matter. Grms.	Nitrogen. Grms.
Eaten,	5816±38.97	83.48±.83
Excreted,	2425± 9.22	36.47±.16
Digested,	3391±40.04	47.01±.85
Per cent. digested,	58.30± .69	56.31±1.02

Summary of Probable Errors of Co-efficients.

For whole period.

December 20 to February 13—

Air-dry matter, ...±.33 per cent.

Nitrogen, ...±.50 per cent.

For ten-day averages.

Air-dry matter, ...±0.69 per cent.

Nitrogen, ...±1.02 per cent.

Any apparent difference between the average digestibility for the whole period and that computed from the ten-day averages which exceeds the square root of the sum of the squares of the errors of each separately will be significant. That is to say, in the case of the air-dry matter, the smallest significant difference would be

$$\pm\sqrt{0.33^2+0.69^2}=\pm0.76\%$$

and for nitrogen.

$$\pm\sqrt{0.5^2+1.02^2}=\pm1.14\%$$

It should be noted that the error in case of the air-dry matter includes the error due to variations in the amount of hygroscopic moisture remaining in the air-dry samples. The results of the special digestion periods, however, show substantially the same percentage digestibility for air-dry matter as for dry matter, thus indicating that the inclusion of this error is an unnecessary concession.

If it were omitted, the computed error would be considerably reduced. On the other hand, however, the total probable error of one determination of dry matter in the feces, as computed from the result of 12 analyses of the same sample of feces (p 138), amounts to 1.01 per cent, or not very much less than that computed above for the air-dry matter. Accordingly, while it is believed that the allowance for probable error is amply sufficient, it has not seemed wise to reduce it.

Greater accuracy in the weighings of the samples of feces would have materially reduced these errors, but the degree of accuracy attained was amply sufficient for the main purpose of the experiments, which were not planned with reference to the question of variations in digestibility.

In Plate XVII, the irregular red line shows the course of the digestibility as computed from the overlapping ten-day averages, each average being entered on the 6th day of the ten, while the broken black line corresponds to the average computed for the whole period. The dates in every case are those on which the food was eaten. The shaded portion on each side of the black line corresponds to the limit of probable difference due to analytical and other errors as computed above. In other words, any variations of the red line which carry it outside this shaded portion indicate with a good degree of certainty an actual difference in digestibility at that time, while the variations which occur within the shaded portion are susceptible of explanation by possible analytical and other errors. A reference to the plate will show that, while the apparent digestibility varied from time to time, these variations lie, to a considerable extent, within the range of probable error. In every cases, however, there are times when the variation is greater than can be accounted for in this way, and this is true both for the air-dry matter and the nitrogen. It appears also that these large variations did not occur at the same time in the different animals, and therefore are probably not due to any common external conditions. The variations in the digestibility of the nitrogen correspond in a general way, although not exactly, with the variations in the digestibility of the air-dry matter, although the extent of the variation is not the same, it being greater for nitrogen than for air-dry matter in the case of Steers 1 and 3, and less in the case of No. 2. On the whole, it seems likely that the variations in the digestibility of the ration were largely due to variations in the rate of excretion of the feces, with some modifying cause in the case of nitrogen, possibly variations in the amount of metabolic nitrogen excreted. It is to be remembered that these results were obtained upon exclusive feeding with dry hay, and that it is possible that with a somewhat more laxative diet the variations would have been less. It has not been possible, however, to trace any connection between these apparent variations in the rate of excretion and the percentage of dry matter in the feces.

The belief that the variations in digestibility are chiefly due to variations in the rate of excretion of the feces is strengthened by a comparison of the weight of nitrogen digested with that excreted in the urine, as shown on Plate IX. The fluctuations in the apparent digestibility of the nitrogen correspond in the main, of course, to the fluctuations in the weight of nitrogen digested, but as a rule an unusually high or unusually low digestibility of nitrogen does not result in a correspondingly high or low figure for urinary nitrogen. Since we know that the latter follows closely any variations of the nitrogen supply in the food, it seems reasonable to conclude that the amounts of nitrogen actually absorbed were more uniform than appears from the percentage digestibility and that the fluctuations of the latter were caused, at least in part, by an abnormally large or small excretion of feces at certain times.

LIVE WEIGHT AS A MEASURE OF NUTRITIVE EFFECT.

It has become a truism that the live weight, particularly of ruminants, is a very untrustworthy measure of the actual nutritive effect of a ration, both on account of its fluctuations from day to day and because of the diverse causes which may combine to produce those fluctuations. The experiments here reported afford innumerable examples of these daily fluctuations, and likewise show that the chief cause of these fluctuations is, as previous observers have pointed out, the varying consumption of water. A glance at the plates will show that almost invariably the drinking of an unusually large or small amount of water results in an abnormally high or low weight. The live weight in these experiments, it will be remembered, was taken 24 hours after watering, and it seems somewhat surprising that the effect should persist so markedly for so long a time, but that it does cannot be doubted.

Notwithstanding this renewed demonstration of the uncertainties of live weight, however, the attempt to base conclusions upon it, in connection with the determinations of proteid metabolism, has been ventured in these experiments. In so doing, reliance has been placed upon two methods for eliminating, in part at least, some of the above uncertainties, viz., upon long periods of uniform feeding and upon daily weighings throughout the whole experiment.

The importance of the first is self evident. An apparent maintenance for a week or two might easily consist with a real loss of tissue masked by a gain of water or an increase of intestinal contents, or vice versa, but we can hardly suppose that a gain or loss of tissue could go on for two or three months without a manifest effect upon the live weight and the appearance of the animal.

It must be admitted, however, that even a comparison of the average live weights for several days at the beginning and close of a long period may be somewhat deceptive, inasmuch as temporary variations in weight appear to take place, covering periods of several days. Such fluctuations are plainly manifest in the records of live weights as charted in the plates. In order to exhibit them clearly, however, it is necessary to eliminate, so far as possible, the effects of the daily variations in the amount of water consumed. This it has been sought to do by averaging the results for several days in the manner explained in the description of the several experiments. A five-day period was first tried, but this proving too short to eliminate entirely the daily fluctuations, a ten-day period was selected as being convenient for computation.

Applying this first to the water consumed, the average amount has been computed for the 1st-10th days of the experiment, the 2d-11th, the 3d-12th, and so on, in overlapping ten-day periods. These averages are shown graphically by the red lines in the plates, each average being plotted on the 5th day of the ten. These red lines represent the general course of the water consumption, the daily variations being, as the plates show, largely eliminated. In some instances the lines take a peculiar zigzag course, constituting apparent exceptions to this rule. Further study of these cases, however, shows that they generally arise from an unusually large or small consumption of water on two successive days, so that the ten-day period includes alternately six days with a high consumption of water and six days with a low consumption. Were we to take the average for an odd number of days at those times (e. g., 9 or 11) these fluctuations would largely disappear.

It is plain then that by a similar treatment of the daily live weights, the influence of the fluctuations of the water consumption upon them may likewise be practically eliminated. Accordingly, ten-day averages of the live weights have been computed and plotted, as explained in detail in connection with the several experiments, with the results shown in the plates by the red lines.

A study of these plates shows plainly that the influence of the daily variations has largely disappeared. Moreover, the irregularities still remaining in most cases coincide with those irregularities in the averages for water consumed, the origin of which has just been pointed out. In other words these slight fluctuations in the average live weight from day to day are due to the fact that the method of computation employed does not, in these cases, eliminate entirely the effect of varying water consumption.

This practical elimination of the daily variations due to the water consumption, however, serves to bring out more clearly the fluctuations of longer period already referred to. Instances of these are to be found in all the experiments, although they are slightly less marked in the later ones. In some instances they appear to be connected with a change in the feeding, as in the preliminary feeding preceding Experiment VI (Plates V, VI and VII), and in at least one instance (Steer No. 3 in Experiment III, Plate IV), seem plainly due to the retention of food in the digestive tract (impaction). In most cases, however, it has not been found possible to trace any connection between these fluctuations in weight and the conditions of the experiment.

As was stated in the account of those experiments, the daily record of excretion in Experiments VI and VII was undertaken in the hope of throwing some light on the causes of these fluctuations, but without much success. It having been shown by these experiments that the apparent variations in the digestibility of the ration are probably due to variations in the rate of excretion of the feces, we should naturally incline to attribute some, at least, of the variations in live weight to this cause. In this case we should expect a maximum of weight to correspond with a minimum of digestibility, and vice versa. In fact, however, the relation, so far as any can be traced, appears to be rather the reverse, a high digestibility frequently coinciding with a high live weight, and a low digestibility with a low weight. Similarly, a comparison of the course of the live-weight with the weights of fresh feces and urine, fails to show any apparent connection between the two. In some cases, the fluctuations in live weight are more or less simultaneous in all three animals, as at the close of Experiment IV (Plates II, III and IV), and during the time from Feb. 20th to Mar. 5th, 1895, in Experiment VI (Plates X, XI and XII), when the animals were out of the special stalls. On the other hand, however, cases of individual variations by single animals independently of the others are much more numerous. These facts would seem to exclude changes of stable temperature as the cause of the variations. A direct comparison of the two also fails to show any evident connection, and it is questionable whether the variations in temperature were sufficient to cause any marked variation in the production of heat. No noticeable difference was observed in the behavior of the animals at different times, and their surroundings were as nearly uniform as practicable, so that it is improbable that any large differences in the total metabolism resulted from more or less muscular exertion. Perhaps the most plausable explanation of these fluctuations would be one which connected them with variations in the amount of water contained in the tissues of the animal and in the contents of the digestive tract, arising from variations in the amount of water vapor exhaled. But this conjecture could only be verified by respiration experiments in which the exhalation of water was determined, although it is possible that determinations of the relative humidity of the air of the stable, had such been made, might have furnished a clue to the cause.

In the interpretation of these experiments, these fluctuations, like the daily variations, have been regarded as in a sense accidental; that is, they have been assumed to be due to some cause other than a change in the actual weight of dry matter in the tissues of the animal. Accordingly, there has been drawn in each diagram a straight line representing what seems the most probable average rate of gain or loss of tissue-weight. The position of this line has been so chosen as to indicate as fairly as possible what appears to be the general course of the live weight. It need scarcely be said that the location of this line is a matter of judgment, and that very possibly no two persons would exactly agree in regard to it. On the other hand, however, any interpretation of live weights other than a purely mechanical one is necessarily a matter of judgment, and furthermore, the writer does not believe that the difference between the judgments of two competent observers, applied in this manner, would be large enough to very materially affect the final result. Of course, that result can be only an approximation, but it is believed that a much closer approximation to the truth is likely to be reached by this graphic method than by a simple comparison of averages, and that in cases where the total gain or loss is slight, the result may be used with considerable confidence.

The manner of comparing the results upon the proteid metabolism with the gain or loss of live weight, estimated as above described, has already been explained in detail (p. 33), and need not be repeated here. That the final result may include a relatively considerable error is freely conceded. As applied to experiments in which rapid fattening took place, it is questionable whether the method would lead to conclusions of much value. The point to be borne in mind is that in most of these experiments the gain or loss of weight was comparatively small and that consequently the absolute amount of error introduced in this way must be small also.

THE ENERGY OF THE FOOD.

All forms of life of which we have any knowledge manifest themselves through the conversion of potential into kinetic energy, and the essential function of the food of the animal is to serve as a vehicle for the introduction of supplies of energy into the organism. The study of the problem of nutrition from this point of view has already materially helped to unify and simplify our general conceptions of the subject and promises to afford still greater aid in the future.

While the importance of a thorough chemical study of feeding stuffs cannot be overrated, the writer has long been of the opinion that a simpler and more direct, and for many purposes fully adequate method of comparing them might be based on a direct determination of their heats of combustion, as first proposed by Kellner,* and such determinations were made by Mr. J. A. Fries and Mr. M. E. McDonnell in the laboratory of this Station, in 1892, with a form of ice calorimeter, with quite satisfactory results. The manipulation of the apparatus, however, was tedious and the method involved all the complications incident to the use of potassium chlorate as an oxidizing agent. With the devising of the bomb calorimeter by Berthelot and its modifications by Hempel and Atwater, however, it became practicable to multiply determinations, and a study of the energy-content of feeding stuffs has been taken up energetically by numerous investigators.

In the experiments here reported the energy of the food and the disposition of it by the animals was the main object of study, and the results enable us to draw up a partial balance of energy.

THE ENERGY OF THE DIGESTED FOOD.

Precisely as we determine the amounts of digestible nutrients in a feeding stuff by subtracting the quantities found in the feces from the total amounts fed, so we may find the energy of the digested food by subtracting the energy of the feces from that of the total food, and, as in the former case, we may express the relation between the two in the form of a percentage which might be called the digestion coefficient of the energy. In both cases, the presence of metabolic products in the feces introduces an error of uncertain amount, so that the quantities of matter digested and the corresponding amounts of energy are slightly below the truth, but concerning the amount of error as regards energy we have no data.

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*Landw. Jahrb., 9, 685.

Disregarding the presence of these metabolic products, the following table shows the percentages of organic matter and of energy which were digested, that is, which did not reappear in the feces:

Percentage Digestibility.

	Organic matter.	Energy.
EXPERIMENT I:		
Steer 1,	[illegible]	[illegible]
Steer 2,	[illegible]	[illegible]
Steer 3,	[illegible]	[illegible]
EXPERIMENT II:		
Steer 1,	[illegible]	[illegible]
Steer 2,	[illegible]	[illegible]
Steer 3,	[illegible]	[illegible]
EXPERIMENT III:		
Steer 1,	62.44	[illegible]
Steer 2,	[illegible]	[illegible]
EXPERIMENT IV:		
Steer 1,	[illegible]	[illegible]
Steer 2,	[illegible]	[illegible]
Steer 3,	[illegible]	44.11
EXPERIMENT V:		
Steer 1,	[illegible]	[illegible]
Steer 2,	[illegible]	44.73
Steer 3,	[illegible]	[illegible]
EXPERIMENT VI:		
Steer 1,	[illegible]	[illegible]
Steer 2,	60.13	[illegible]
Steer 3,	[illegible]	[illegible]
EXPERIMENT VII:		
Steer 1,	[illegible]	[illegible]
Steer 2,	64.33	[illegible]
Steer 3,	[illegible]	[illegible]
EXPERIMENT VIII (AVERAGE:)		
Steer 1,	[illegible]	[illegible]
Steer 2,	[illegible]	[illegible]
Steer 3,	[illegible]	[illegible]

In every instance the proportion of the total energy of the food contained in the digested portion is less than the percentage of organic matter digested. Kellner's experiments* gave the same results, viz:

Percentage Digestibility.

	Organic matter.	Energy.
Ox A,	67.1	[illegible]
Ox B,	[illegible]	[illegible]

The determinations, already mentioned, made by Messrs. Fries and McDonnell at this Station, afford a further instance of the above fact. The methods and apparatus employed in these determinations were substantially those described by Rodewald,† potassium chlorate being used as the oxidizing agent. In view of the greater convenience and accuracy of the bomb calorimeter now in use, any elaborate description of the method pursued would be superfluous. As a check upon its accuracy the following determinations of the heats of combustion of starch and of sugar cane were made:

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* *Loc. cit.*, pp. 310 and 317.

† Jour. f. Landw. 31, 407.

Heats of Combustion per Gram of Dry Matter.

	Starch. Cal.	Cane sugar. Cal.
By ice calorimeter,	4.118	3.971
	4.112	3.959
	4.093	
	4.122	
	4.112	
	4.123	
	4.133	
Average,	4.123	3.866
By Thompson-Stohmann method,*	4.116	3.965
By bomb calorimeter:*		
Stohmann,	4.183	3.955
Berthelot,	4.228	3.962

It would appear from the above results that the method is capable of yielding quite accurate results, those upon starch in particular corresponding very closely with those obtained by Stohmann by the potassium chlorate method. The method involved, however, the use of comparatively small quantities of the substance so that the possible range of error in individual cases is somewhat large and the results are undoubtedly somewhat lower than would be obtained by the use of the bomb calorimeter.

In connection with an experiment upon the influence of variety and rate of seeding upon the yield of forage corn, the main results of which have already been reported,† four digestion trials with green forage corn were made, each with two sheep. The results of these, so far as the digestibility of the organic matter and the total energy were concerned, were as follows:

Percentage Digestibility.

	Organic matter.	Energy.
PERIOD 1:		
Sheep 1,	65.61	61.75
Sheep 2,	65.46	61.26
PERIOD 2:		
Sheep A,	70.53	65.26
Sheep B,	69.11	65.67
PERIOD 3:		
Sheep 1,	67.20	62.58
Sheep 2,	68.07	63.01
PERIOD 4:		
Sheep A,	71.51	67.24
Sheep B,	70.20	66.67

U. S. Dep't Agr. Office of Experiment Stations, Bul. 21, p. 128.

†Penna. Expt. Station, Bulletin 15 and Annual Report for 1891, p. 17.

These results are fully in accord with those already cited, and all serve to demonstrate the fact that the energy of the food is relatively less digestible than its organic matter.

This is simply another way of saying that the organic matter of the feces has a higher heat value than the organic matter of the food, chiefly due, as Kellner* shows, to the fact that the undigested portions of the "crude fiber" and "nitrogen free extract" of the coarse fodders have a higher heat value than the digestible portions. In Experiment VIII the amount of crude fiber in the ration was considerably reduced, while a large proportion of its nitrogen-free extract was contained in grain. The feces in this experiment show a larger proportion of nitrogen-free extract, a lower percentage of crude fiber, and a lower heat value than those of the other experiments, and, corresponding to the latter fact, the difference between the percentage digestibility of organic matter and that of energy is markedly less. These facts would seem to indicate a less difference in the heat values of total and of digestible nitrogen-free extract in the case of grains than that found by Kellner in the case of coarse fodders.

THE ENERGY OF THE URINE.

To find the available energy of a ration, we must subtract from the energy of the digested food the energy of the corresponding excretory products. These consist of the metabolic products contained in the feces and urine and the hydrocarbons of respiration. The energy of the fecal metabolic products is included in that of the total feces and is therefore deducted in computing the apparent digestibility. The energy of the urine has quite commonly been computed from its nitrogen or, what amounts to the same thing, the total nitrogen of the digested food has been assumed to take the form of urea, and a corresponding deduction has been made from its energy.

Rubner† was the first to show that this assumption regarding the energy of the urine is seriously erroneous, and that the urine can by no means be regarded, in such experiments, as a simple solution of urea. Making direct determinations of the energy in the urine and comparing it with the amount of nitrogen present, he obtained the following results:

Energy per Gram of Nitrogen.

In urea, ...	5.41 Cal.
In urine from dog fed on extracted lean meat, ...	6.69 Cal.
In urine from dog fed on lean meat, ...	7.45 Cal.
In urine from fasting dog, ...	8.49 Cal.

In other words, the potential energy carried off in the urine of a

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Loc. cit., p. 299.

† Zeit. f. Biol., 21, 250.

carnivorous animal was found to be from 24 to 57 per cent. greater than that of the urea corresponding to the amount of proteids metabolized. This excess was found to arise from the presence in the urine of less highly oxidized nitrogenous substances, and also, in the last two cases, from the fact that the extractives of the meat or of the nitrogenous tissue are excreted unchanged in the urine to a considerable extent. The same facts are reflected in the ratio of nitrogen to carbon in the urine. For urea, this ratio is 1:0.428. In three experiments in which extracted lean meat was fed, the ratio in the urine averaged* 1:0.523.

But if the assumption that the urine is substantially a solution of urea leads to such large errors in the case of carnivorous animals, it is still less admissable in the case of herbivorous animals, where we know that, under ordinary conditions, a not inconsiderable proportion of the nitrogenous matter of the urine consists of hippuric acid. Moreover, the urine of domestic herbivora contains a relatively large amount of non-nitrogenous organic matter. Henneberg† found that from 26.7 to 30.0 per cent. of the organic matter in sheep urine was neither urea nor hippuric acid, while from 95 to 100 per cent. of the total nitrogen was contained in these two substances. G. Kühn‡ in his extensive respiration experiments on oxen, already quoted in another connection, assuming that all the nitrogen of the urine was in the form either of hippuric acid or urea, found that from 40.05 to 67.64 per cent. of the total carbon of the urine was present in non-nitrogenous substances. He likewise showed that the addition of proteids (gluten) to the ration resulted in a marked increase of the non-nitrogenous organic matter of the urine, as well as of the total carbon and nitrogen, thus confirming for herbivora Rubner's results on carnivora.

Kellner's experiments on maintenance,§ likewise cited above, when computed on the same assumption, give the same result, viz:

Carbon in Non-nitrogenous Compounds.

	Grms.	Per cent. of total C.
Ox A,	94.35	46.43
Ox B.	69.32	42.97

Direct determinations of the potential energy of the urine confirmed these results. the amount being larger than could be accounted for by the urea and hippuric acid present, as the following comparison shows:

Loc. cit., p. 279.

†Nene Beiträge, etc., p. 119.

‡Landw. Vers. Stat., 44, 348, 404, 474, 529.

§Landw. Vers. Stat., 47, 283 and 308.

Energy of Urine.

	Ox A. Cal.	Ox B. Cal.
TOTAL ENERGY:		
In hippuric acid,	821.3	715.9
In urea,	271.4	199.6
Total computed,	1,092.7	915.5
By direct determination,	1,945.0	1,549.4
ENERGY PER GRAM OF NITROGEN:		
Computed,	17.82	19.63
Determined,	31.74	33.22

In the experiments here reported, the total energy of the urine was determined in the manner described under the several experiments, but the hippuric acid was not determined. The results of the energy determinations, calculated per gram of total urinary nitrogen are:

Energy per Gram of Nitrogen.

	Steer 1. Cal.	Steer 2. Cal.	Steer 3. Cal.
Experiment III,	37.79	28.35	....
Experiment V,	40.64	34.25	28.82
Experiment VI,	19.29	18.01	12.47
Experiment VII,	26.02	....	....
Experiment VIII:			
Period I,	11.50	7.12	5.80
Period II,	10.98	14.42	16.10

The results are quite irregular and, as was pointed out, the range of possible error in some of the determinations is rather large. They are sufficient, however, to show that a computation based on the assumption that all the nitrogen existed as urea (1 grm. N in urea =5.434 Cal.) would in some cases have been almost ludicrously erroneous.

In those of Kühn's and Kellner's experiments in which coarse fodder alone or coarse fodder and starch were fed, the average proportion of the total urinary nitrogen which was in the form of hippuric acid was 17.6 per cent. Assuming the rest of the nitrogen to be in the form of urea, this corresponds to 17.21 Cal. per gram of nitrogen. In some of our experiments, this figure is largely exceeded, while in others it is not reached. In view, however, of the fluctuations in the proportion of hippuric acid excreted at different times and under different conditions, little weight attaches to this comparison. Experiments are now in progress which it is hoped may throw some light upon the great apparent variations in the relative amount of energy in the urine. In the meantime, it is evident that in metabolism experiments the energy of the urine must be determined directly if accurate results are to be reached.

For the main purpose of these experiments, the important thing is the total amount of energy in the urine, and while the determinations of this are not in all respects satisfactory, it is believed that the error involved is small in proportion to the total energy of the rations.

ENERGY OF HYDROCARBONS.

A further deduction from the energy of the apparently digested food must be made for the hydrocarbons produced by the fermentation of the non-nitrogenous nutrients in the alimentary canal. The amount of energy thus carried off in these experiments we are compelled to estimate in the manner explained on p. 35, and with the results stated under the several experiments.

AVAILABLE ENERGY OF THE FOOD.

Subtracting from the total potential energy of the food the amounts carried off unused in the feces, urine and methan, the remainder is what may be called the available energy of the food, i. e., it represents that portion of the total energy which is capable of being converted into heat or otherwise utilized in the organism.

In such computations, the deduction to be made for the energy of the urine will differ slightly from the amounts actually determined (or estimated) in the several experiments for the reason that in some of these cases the urine contained nitrogenous compounds derived from body proteids metabolized, while in other cases a part of the proteids of the food was stored up in the body. We may probably assume, without serious error, however, that had the animals been exactly in nitrogen equilibrium the energy-content of the urine per gram of nitrogen would not have been materially different from that observed, and on this basis may compute the energy of the urine from the digestible nitrogen of the food. Thus, in the case of Steer 1, in Experiment I, we make the following computations:

Total energy of food,		17,373 Cal.
Energy of feces,	7,850 Cal.	
Energy of urine (20.16 grm. N. @ 16.6 Cal),	335 Cal.	
Energy of methan (estimated),	1,232 Cal.	
		9,417 Cal.
Available energy,		7,956 Cal.
Digestible organic matter,		2,219 grms.
Available energy per gram of digestible organic matter,		3.6 Cal.

The available energy of the same ration computed upon the customary basis, derived chiefly from Rubner's experiments, viz.: 4.1 Cal. per gram of proteids and carbohydrates and 9.4 Cal. per gram of fat, is:

Digestible proteids, ...	108 grms.	@ 4.1 Cal.	8,909 Cal.
Digestible non-proteids, ...	18 grms.		
Digestible crude fiber, ...	727 grms.		
Digestible nitrogen-free extract, ...	1,320 grms.		
Digestible ether extract,.......	46 grms.	@ 9.4 Cal.	432 Cal.
Digestible Organic matter,....	2,219 grms.		9,341 Cal.

Digestible energy per gram of digestible organic matter,... 4.2 Cal.

The following table contains the results of similar computations for the several experiments of this series:

Available Energy of Food.

Food.	Total digestible organic matter. Gms.	Actual.		Computed with Rubner's factors.	
		Total. Cal.	Per gram digestible organic matter. Cal.	Total. Cal.	Per gram digestible organic matter. Cal.
EXPERIMENT I. Timothy Hay.					
Steer 1, ...	2,219	7,956	3.59	9,341	4.21
Steer 2, ...	2,122	7,588	3.58	8,939	4.21
Steer 3, ...	2,019	7,191	3.56	8,522	4.22
EXPERIMENT II. Timothy Hay.					
Steer 1, ...	2,255	8,144	3.61	9,497	4.20
Steer 2, ...	2,597	9,590	3.68	10,929	4.21
Steer 3, ...	2,243	8.084	3.60	9,440	4.21
EXPERIMENT III. Timothy Hay and Corn Meal.					
Steer 1, ...	1,958	6,022	3.07	8,378	4.28
Steer 2, ...	2,207	7,430	3.37	9,420	4.27
EXPERIMENT V. "Cotton-seed Feed."					
Steer 1, ...	2,297	7,876	3.43	10.186	4.43
Steer 2, ...	2,520	8,996	3.57	11,127	4.41
Steer 3, ...	2,982	11,325	3.80	13,228	4.44
EXPERIMENT VI. Timothy Hay.					
Steer 1, ...	3,077	11,130	3.62	12,982	4.22
Steer 2, ...	3,132	11,318	3.61	13,244	4.23
Steer 3, ...	3,035	11,324	3.73	12,851	4.23
EXPERIMENT VII. Timothy Hay and Corn Starch.					
Steer 1, ...	3,293	11,955	3.63	13,809	4.19
Steer 2, ...	3,285	11,904	3.62	13,835	4.21
Steer 3, ...	3,189	11,557	3.62	13,404	4.21
EXPERIMENT VIII. Wheat Straw, Corn Meal and Linseed Meal.					
Steer 1, ...	3,006	11,634	3.87	13,077	4.35
Steer 2, ...	3,356	12,976	3.87	14,565	4.34
Steer 3, ...	3,108	12,030	3,87	13,554	4.36

As was the case in Kellner's experiments, the available energy of the digestible organic matter of the food is in every case materially less than that computed by the use of the usual factors. The average available energy of one gram of digestible organic matter in meadow hay was found by Kellner to be 3.5 Cal. The average of our three experiments on timothy hay is 3.62 Cal. per gram of digestible organic matter.

The difference between the observed and computed amounts of available energy arises in part from the relatively large amount of energy carried off in the urine in proportion to its nitrogen, and in part doubtless from the low heat value of the non-proteids, but is chiefly due to the loss of energy in methan. Since, now, the formation of methan in our experiments is estimated on the basis of the same experiments which yielded Kellner the result quoted above, our results are, properly speaking, not a confirmation but simply an illustration of his. Inasmuch, however, as it appears highly probable that the production of methan is fairly constant under similar conditions, our results upon coarse fodder at least may be considered as fairly representing their available energy and as in a sense confirmatory evidence of its being less than that ordinarily computed. How far the production of methan may be modified by the introduction of grain into the ration, we can only conjecture, and hence our results on the mixed ration have much less value. It seems not impossible that heavy feeding with grain, in the case of fattening animals, may give rise to an increased production of this gas, resulting in an apparently lessened nutritive effect of the digested food. In any event, it is clear that the determination of hydrocarbons in the respiratory products must henceforth constitute an essential part of metabolism experiments upon herbivora.

The above results may be put in a more directly available form by computing the amount of available energy contained in one gram of dry matter in the food. The following table contains the results of the computation for the three experiments in which a single feeding stuff (timothy hay) was fed.

Available Energy per Gram of Dry Matter in Timothy Hay.

	Total dry matter. Gms.	Available energy. Cal.	Available energy per gram of dry matter. Cal.
EXPERIMENT I:			
Steer 1,	4,003	7,956	1.987
Steer 2,	4,003	7,588	1.896
Steer 3,	4,003	7,199	1.798
EXPERIMENT II:			
Steer 1,	4,726	8.144	1.702
Steer 2,	4,726	9.590	2.029
Steer 3,	4,726	8,064	1.711
EXPERIMENT VI:			
Steer 1,	5,566	11.130	2.000
Steer 2,	5,566	11.318	2.034
Steer 3,	5,566	11,324	2.034
Average, Steer 1,			1.896
Average, Steer 2,			1.986
Average, Steer 3,			1.848
Average of all,			1.910

On the average of these nine determinations, one gram of dry timothy hay was able to contribute to the needs of the animal an average of 1.9 Cal. of energy. The five experiments upon meadow hay cited by Kellner, computed in the same way, give a slightly higher figure, viz: 2.0 Cal. of available energy per gram of dry matter.

Finally, we may compute the percentage of the total energy of the timothy hay which was available in the organism with the following results:

Percentage of total energy of Timothy Hay available.

	Total energy. Cal.	Available energy. Cal.	Per cent. available.
EXPERIMENT I:			
Steer 1,	17,373	7,956	45.79
Steer 2,	17,373	7,588	43.68
Steer 3,	17,373	7,191	41.39
EXPERIMENT II:			
Steer 1,	20.898	8,144	38.97
Steer 2,	20,898	9,590	45.89
Steer 3,	20,898	8,064	38.68
EXPERIMENT VI:			
Steer 1,	24.635	11.130	45.18
Steer 2,	24.635	11.318	45.94
Steer 3,	24,635	11,324	45.97
Average, Steer 1,	20,969	9.077	43.29
Average, Steer 2,	20,969	9,499	45.30
Average, Steer 3,	20,969	8,866	42.28
Average of all,	20,969	9,147	43.62

On the average of these nine experiments on three animals, 43.6 per cent. of the total energy of the food was available to the organism. The results of the individual experiments vary considerably, and as has been repeatedly pointed out, the result is based in part on estimates. Tentatively, however, and until it is replaced by more accurate figures, we may, by using this percentage after the manner of a digestion co-efficient, compute the available energy of a sample of timothy hay from its total energy in substantially the same way as we now compute its digestible matter and with results approximating much more closely to the truth than those calculated from the digestible matter by the use of the current factors.

In view of the present tendency to regard the food as a source of energy, the writer ventures to suggest that determinations of the availability of the gross energy of the more important feeding stuffs are as urgently needed as was a knowledge of their digestibility forty years ago when Henneberg and Stohmann began their classic investigations. The methods to be pursued in such determinations have already been in the main worked out, but as yet only isolated results are available. While investigations of this sort appear somewhat abstract in character and remote from the practical demands of the stock feeder, and while they require patience and involve the use of somewhat expensive apparatus, yet the data to be thus gained are of fundamental importance to both the science and the rational practice of feeding.

As compared with Kellner's results upon meadow hay, the distribution of the gross energy of the food, expressed in percentages, was as follows:

	Timothy hay.	Meadow hay. (Kellner.)
In feces, per cent.,	47.27	41.8
In urine, per cent.,	2.61	6.1
In methan, per cent.,	6.50	7.3
Available, per cent.,	43.62	44.8
	100.00	100.00

THE MAINTENANCE RATION.

The Quantity of Food.

Under the several experiments, the amounts of food required for maintenance, expressed in terms of energy, have already been computed. The method of computation employed in these cases, as also by Kellner, involves, however, certain assumptions which call for more specific mention.

In no case did the ration fed appear to be an exact maintenance ration. Larger or smaller gains or losses of flesh and of fat by the animals occurred in every instance. In computing the balance of energy, the energy of any loss by the body has been added to the energy of the food, while that of any gain by the body has been added to the energy of the excreta. The difference between these two represents, within the limits of experimental error, the amount of energy liberated in the body and which we presume ultimately takes the form of heat. Up to this point, we are substantially dealing with facts. The above difference between the energy of food plus loss and that of excreta plus gain, however, has been regarded as constituting the maintenance ration. In other words, it has been assumed that, whether it be gaining or losing tissue, the animal evolves just the amount of heat (energy) required to maintain its body temperature; that if its food is insufficient, it draws upon its body for just enough to make up the difference and that if its food be in excess it stores up the whole of the excess energy in its tissues.

In the case of insufficient food, Rubner's† well known investigations upon the isodynamic equivalence of the nutrients show that the assumption is well founded, and that the heat production of such an animal represents the minimum demand of the organism. As regards the disposal of excess food by the body, the case is not so clear, owing to the paucity of experimental data, but there are not wanting indications that under such circumstances the heat production is increased and that only a part of the energy of the excess food is stored up in fat or flesh. Especially pertinent to the case in hand are Kellner's computations of the results of G. Kühn's* experiments upon the production of fat from starch, which show that barely half the potential energy of the excess food was contained in the fat and proteids gained by the animals. It is thus rendered probable that the deductions made for the energy stored up in the body in determining the amount required for maintenance are too small and the results for the maintenance ration too high, while we incline to regard with more confidence the results of those experiments in which there was a loss from the body, in so far as the nature of that loss was accurately determined. Fortunately, the gain in most of the experiments was small, and it appears possible also that a slight amount of excess food may be relatively better utilized than a larger one. Accordingly, we may fairly take the results as they stand, with the consciousness that they are likely to be slightly too high rather than too low.

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†Zeit. f. Biol., 19, 312; 21, 250.

As already explained, all results have been calculated to 500 kgs. live weight on the assumption that the amount of the maintenance ration is proportional to the two-thirds power of the weight. Excluding the results of Experiments III, IV and V for the reasons stated in the account of those experiments, we have the following results:

Energy per 500 Kgs. Live Weight.

	Stable temperature.	Steer 1. Cal.	Steer 2. Cal.	Steer 3. Cal.
Experiment I,	About 50° F.	12,260	13,780	11,650
Experiment II,	About 50° F.	12,000	12,460	11,400
Experiment VI,	About 48° F.	12,690	12,510	12,730
Experiment VII,	About 57° F.	13,110	12,620	16,040
Experiment VIII,	About 57° F.	11,467	10,278	11,324
Average,	....	12,307	12,330	12,629
Average, excl. Expt. I, Steer 2, and Experiment VII, Steer 3,	....	12,307	11,967	11,776
Average of Expts. I, II and VI, on coarse fodder only,	....	12,317	12,917	11,925
Average of I, II and VI, on coarse fodder only, excl. Expt. I, Steer 2,	....	12,317	12,485	11,925
Average of Expts. I, II, VI and VII,	....	12,515	12,843	12,955
Average of Expts. I, II, VI and VII, excl. Expt. I, Steer 2, and Expt. VII, Steer 3,	....	12,515	12,530	11,927

Of the above experiments, Nos. I, II and VI, were upon coarse fodder exclusively and No. VII upon coarse fodder and starch. In these experiments, the proportions of the several nutrients were not widely different and the rations are fully comparable with those of Kühn's and Kellner's experiments. The average of the 12 single results of these four experiments is:

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*Landw. Vers. Stat., 44, 557.

12,771 Cal. at 51 degs. F.

while the average of the nine experiments by Kühn and Kellner, computed to 500 kgs. live weight in the same manner (compare p. 24) is:

12,952 Cal. at 61 degs. F.

If it be considered more correct to omit the seemingly exceptional results on Steer 2 in Experiment I, and Steer 3 in Experiment VII, and likewise the three of Kühn's and Kellner's results in which the energy of the food is computed, the agreement becomes somewhat less close, viz.:

Kühn-Kellner,	13,008 Cal.
These experiments,	12,324 Cal.

It is questionable, however, whether we are justified in arbitrarily rejecting the results of two of our own experiments. If we include them, but omit the three of Kühn's & Kellner's above, we have as the general average:

12,850 Cal.

a result differing from Kellner's average by only 150 Cal., an amount which, in view of the variations of the individual experiments, is entirely insignificant.

As the general result of both these series of experiments, we may place the average maintenance of a steer weighing 500 kgs. and receiving only or mainly coarse fodder at:

13,000 Cal. of available energy.

at a stable temperature of 50 to 60 degrees F. after making a deduction for the loss of energy in the form of methan. As already pointed out, this differs from the result announced by Kellner (24,000 Cal. per 1,000 kgs. live weight) only in the method of computation to uniform live weight.

COMPARISON WITH EARLIER RESULTS.

Of the results cited in the earlier portion of the paper, only those of Henneberg and Stohmann, and those of Armsby, Frear and Patterson (pp. 11 and 20), admit of a direct comparison with the above average. These results, together with Wolff's standard, may be concisely summarized as follows:

Henneberg and Stohmann,	16,587 Cal.
Armsby, Frear and Patterson,	13,150 Cal.
Wolff's standard,	18,540 Cal.

In comparing the earlier with the later results, it must be remembered that in the former no account is taken of the production of methan. If we estimate the amount of the latter from the amount of crude fiber and nitrogen-free extract digested, as in our own experiments, the amounts are reduced to the following:

	Estimated methan. Grms.	Equivalent energy. Cal.	Net energy for maintenance. Cal.
Henneberg and Stohmann,	174	2,306	14,282
Armsby, Frear and Patterson,	131	1,735	11,415
Wolff's standard,	182	2,411	16,129

The earlier result of the writer and his associates is less by 1,585 Cal. than the above average of 13,000 Cal., but is not lower than some of the individual results from which that average is derived. Henneberg and Stohmann's average exceeds that here computed by 1,282 Cal., but is not higher than some of the single results. In both of these cases, the experimental periods were rather short and no respiration apparatus was used. Neither would seem, therefore, to afford any ground for questioning the substantial accuracy of Kellner's average, confirmed by the writer's later results. Wolff's standard, on the other hand, is higher than any single result and exceeds the average by 3,129 Cal. or nearly 25 per cent.

Whether the addition made by Wolff to Henneberg and Stohmann's results on account of the rather high stable temperature in the latter experiments was warranted can hardly be determined from the data at hand. The temperature in a good barn, however, will not often fall below 40 degrees F., while in but few of the experiments here reported did it exceed 60 degrees F., and in most cases was nearer 55 degrees F. It certainly seems questionable whether a difference of 10-15 degrees in stable temperature would require an increase of 25 per cent. in the maintenance ration.

In most of the numerous experiments by Sanborn cited in the earlier part of this paper more or less gain in weight took place. As was then pointed out, the experimental methods were not the most refined and but few details were reported. The results are quite irregular, and those of a single experiment seem of doubtful value. If, however, we average a considerable number of the results, we may perhaps obtain a fair basis for some comparisons. Taking the 18 experiments tabulated on p. 17, as fairly representative of his later results, we find an average gain of live weight of 0.31 kgs. produced by a ration containing:

Digestible proteids,	528 grms.
Digestible carbohydrates,	3,097 grms.
Digestible fat,	163 grms.
Computed energy,	16,371 Cal.

If we assume the gain in weight to have had the composition found by Lawes and Gilbert, the 310 grms. of gain consisted of:

Water,	76 grms.
Ash,	5 grms.
Proteids,	24 grms.
Fat,	205 grms.
	310 grms.
Equivalent energy,	2,064 Cal.

The amount of methan probably produced, computed, as before, from the carbohydrates of the ration, is 141 grms., equivalent to 1,866 Cal. Subtracting the energy contained in the gain and that contained in the methan from that computed to be contained in the digestible food, we have for the amount set free in the body 12,441 Cal., or only 559 Cal., less than the computed maintenance ration.

Not very much weight attaches to this result considered as a determination of the maintenance ration, but it is important as showing that the average result of Sanborn's experiments is not inconsistent with the conclusion drawn from more exact experiments.

Moreover, Sanborn's rations were in most cases mixed rations of coarse fodder and grain and, as will presently appear, the indication of the writer's experiments is that under those circumstances somewhat less available energy is required for maintenance than upon exclusive coarse fodder. On the other hand, however, the result computed from Sanborn's average is decidedly below Wolff's standard.

RELATIVE VALUE OF COARSE FODDER AND GRAIN.

Experiment VIII differs from the others in the fact that the larger proportion of the digestible matter was supplied in the form of grain (corn meal and linseed meal). Since the digestibility of the wheat straw used was not determined separately, it is not possible to state exactly the amount of digestible matter derived from it. If, however, we assume for it the following average digestion coefficients, we may make a sufficiently accurate approximation to it for the present purpose.

Assumed Digestibility of Wheat Straw.

Proteids,	26 per cent.
Non-proteids,	100 per cent.
Crude fiber,	52 per cent.
Nitrogen-free extract,	40 per cent.
Ether extract,	27 per cent.

Amounts per Day Digested from Wheat Straw.

Proteids,	14.2 grms.
Non-proteids,	16.2 grms.
Crude fiber,	319.9 grms.*
Nitrogen-free extract,	363.6 grms.
Ether extract,	10.2 grms.
Total,	721.7 grms.

In other words, of the total digested organic matter of the rations, the straw contributed approximately the following percentages:

Steer 1,	24.0 per cent.
Steer 2,	21.5 per cent.
Steer 3,	23.2 per cent.

The average maintenance ration computed from the results of this experiment is:

11,023 Cal. at 57 degs. F.

or nearly 1,750 Cal. less than the average for the experiments on coarse fodder, while the average temperature is only 6 degs. F. higher. Moreover, the results for each individual animal are lower in this period than in any other, the average difference being:

Steer 1,	1,048 Cal.
Steer 2,	2,565 Cal.
Steer 3,	1,631 Cal.

There was no obvious difference in the conditions of the experiment other than the difference in the character of the food which could explain this difference in the results.

It might, of course, be objected that the estimated amount of methan produced in these experiments was calculated by the use of data obtained from experiments with coarse fodder and that less may have been produced in this case. In the first place, however, in view of Kühn's results, such a supposition is not exactly probable, and in the second place the total estimated production of methan was equivalent to but 1,600 Cal., so that even the assumption that its formation was entirely suspended would fail to account fully for the observed difference. Too much weight, of course, should not be attached to a single result of this kind, particularly in view of the approximate nature of some of the data entering into the computation. At the same time, the indications are strongly in the direction pointed out.

We are naturally inclined to connect this with the diminished proportion of crude fiber in the ration, particularly in view of Wolff's† conclusion that the crude fiber in the ration of the working horse is valueless as a force-producer. The percentage of the total digestible organic matter supplied by the crude fiber in these experiments was:

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*Average total amount actually digested, the computed amount being 352.7 gms.

†Landw. Jahrb. 16, Supp. III, 97.

Digested Crude Fiber in per cent. of Total Digestible Organic Matter.

	Steer 1.	Steer 2.	Steer 3.
Experiment I,	32.76	32.19	32.59
Experiment II,	31.31	33.15	33.67
Experiment VI,	36.04	35.76	35.55
Experiment VII,	24.45	24.42	23.17
Experiment VIII,	10.35	11.05	8.94

In the first four cases, an average of 31.25 per cent. of the digestible organic matter was supplied by the crude fiber as compared with 10.11 per cent in the last.

Kellner* computes the energy content of the "digestible" crude fiber at 4.2196 Cal. per gram. G. Kühn† computes as the average of twenty experiments that approximately 9.76 per cent. of the carbon of the digested crude fiber was evolved as methan, which is equivalent to 0.058 grams of methan or .7683 Cal. per gram of crude fiber. Subtracting this from Kellner's result, we have 3.4513 Cal. of "available" energy per gram of digested crude fiber, or in round numbers 3.45 Cal. If now we subtract the available energy of the crude fiber computed on this basis from the total available energy of the rations, we obtain the following figures:

Energy per 500 Kgs. Live Weight, after deducting Energy of Crude Fiber.

	Steer 1. Cal.	Steer 2. Cal.	Steer 3. Cal.
Experiment I,	9,436	11,253	9,028
Experiment II,	9,266	9,267	8,393
Experiment VI,	8,586	8,594	8,598
Experiment VII,	10,140	9,819	13,225
Experiment VIII,	10,447	9,183	10,387
Average I, II, VI and VII,	9,357	9,733	9,811

This method of computation somewhat increases the relative differences between the single experiments, but the difference between Experiment VIII and the average of the others largely disappears, the general average being:

Loc. cit., p. 300.

†*Loc. cit.*, p. 571.

Experiments 1, II, VI and VIII, ...	9,634 Cal.
Experiment VIII, ...	10,006 Cal.

That is, we obtain, as did Wolff in his experiments on the horse, on the whole more concordant results by omitting the crude fiber from our computations entirely.

The interpretation of the result, however, is not so simple a matter. In the first place, it is to be remarked that the figures on p. 156 represent (aside, of course, from experimental errors) the amounts of energy actually liberated in the body, since the energy of all the waste products is taken account of. Since the animals did practically no external work, this energy may be presumed to have ultimately taken the form of heat. If, then, 11,023 Cal. sufficed to cover the loss of heat by the animals in Experiment VIII, the 12,771 Cal. set free in the other experiments must imply the (from this point of view) unnecessary evolution of 1,748 Cal.

The heat undoubtedly evolved during the fermentation of the crude fiber in the alimentary canal has generally been regarded, in discussions of the nutritive value of that substance, as waste heat—that is, as heat unavailable to the organism. It is by no means clear to the writer, that this is necessarily the case. It seems an entirely plausible conjecture that the heat thus generated might enable the animal to oxidize a correspondingly less amount of its own substance or of the actually digested food and thus might be indirectly utilized, but in the absence of any experimental evidence on this point it must remain simply a conjecture.

Since it has been shown, however, that the crude fiber does not occupy an exceptional position in this respect but that the nitrogen-free extract suffers a similar fermentation and to nearly as great an extent, the supposed loss of energy in this process ceases to be available as an explanation of the apparent lack of nutritive value of the former.

The only other apparent explanation lies in the increased work imposed on the digestive organs by the crude fiber, particularly in its mastication and re-mastication. This is undoubtedly considerable. Zuntz* estimates that the work of mastication by the horse requires, in the case of hay, an amount of energy equivalent to that produced by the oxidation of 11.2 per cent. of the digested portion, and in the case of oats, an amount equivalent to 2.8 per cent.

The mixed ration of Experiment VIII contained somewhat more crude fiber than average oats, but showed about the same percentage digestibility of the dry matter. If we may apply the above percentages to the average available energy of our rations we shall have:

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*Exp't Station Record, 7, 548.

Estimated Energy for Mastication.

Coarse fodder alone, Expts. I, II, VI and VII, 12,771 Cal. x 0.112,	1,430 Cal.
Mixed ration, Expt. VIII, 11,023 Cal. x 0.028,	309 Cal.
Difference,	1,121 Cal.

Computed Energy of Digested Crude Fiber.

Coarse fodder alone, Expts, I, II, VI and VII,	3,137 Cal.
Mixed ration, Expt. VIII,	1,018 Cal.
Difference,	2,119 Cal.

These tentative computations make it appear that the additional energy required to masticate the more bulky and indigestible rations of Experiments I, II, VI and VII, as compared with the more concentrated ration of Experiment VIII, was but little more than half that supplied by the additional crude fiber of the former. How far Zuntz's estimates are applicable to ruminants, however, and what further amount of energy was required for moving the more bulky ration through the alimentary canal, it is difficult to say, but it does not seem at all an impossible supposition that the re-mastication and transportation of the extra crude fiber might have consumed the remaining 1,000 Cal., particularly in the light of v. Nathusius' suggestion* that the energy required to move the food through the digestive apparatus will be approximately proportional to the square of its weight, since if the amount of food is doubled, e. g., not only is the mass to be moved twice as great but it must be moved twice as fast.

It may be pointed out, however, that in order to explain Wolff's results and our own on this hypothesis, it is not only necessary to admit that the energy consumed in the digestion of the total crude fiber is equal to the total available energy of its digestible portion, but still further we must regard the heat into which the energy thus expended is ultimately transformed as waste heat—that is, we must suppose that the evolution of the heat necessary to maintain the normal body temperature goes on independently of at least this particular form of muscular activity. But since all consumption of food involves some muscular exertion, with consequent evolution of heat, it would appear that upon this hypothesis we must separate the apparent maintenance ration of the animal into two parts: a constant one corresponding to that amount of total metabolism necessary to maintain the body temperature, and presumably represented by the metabolism of the fasting animal, and a variable one depending on the amount and character of the food consumed, and giving rise to an increased production of heat which is of no use to the animal.

Landw. Jahrb., 20, [illegible].

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There are not wanting indications that such may be the case, as for example, the well-known experiments of Henneberg and Stohmann* upon the influence of eating on the excretion of carbon di-oxide and those of v. Mehring & Zuntz† showing an increased consumption of oxygen consequent upon the introduction of soluble nutrients into the alimentary canal; while their introduction directly into the blood had no such effect. Zuntz‡ likewise states (presumably as the result of short trials with his form of respiration apparatus) that the oxygen consumption of the horse is increased 10.7 per cent. when the animal is fed hay and oats and 19.8 per cent. when it is fed hay only.

On the other hand, Rubner|| in his experiments upon the replacement values of nutrients, found no increase of the excretion of carbon di-oxide by dogs and rabbits when food was given to a previously fasting animal, provided the amount of food did not exceed the maintenance ration. It is quite conceivable, however, that the bulky and relatively indigestible food of herbivora may behave quite differently in this respect, but the experimental evidence now available is too meagre to justify anything more than a tentative opinion. The question is one upon which accurate experiments, which shall include measurements of the metabolism of energy as well as of matter, are greatly needed.

The Minimum of Proteids.

The amount of true proteids (proteid N x 6.25) contained in the several rations fed, together with the gain or loss of the nitrogen by the animals, have already been stated under each experiment.

In bringing these results together for comparison it is desirable to compute them to the uniform live weight of 500 kgs. In the similar reduction of the energy of the rations it has been assumed that this will vary in proportion to the 2-3 power of the live weight. The proteid metabolism, however, appears to vary with the mass of proteids in the body rather than with its surface, and accordingly the amount of proteids digested per head has been increased or diminished in proportion to the live weight, with the results following:

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*Neue Beitrage, etc., p. 157.

†Archiv. ges. Physiol., **32**, 173.

‡*Loc. cit.*, p. 548.

||Zeit. für Biol., **19**, 334.

	Digested proteids per day and 500 kgs. live-weight. Grms.	Available energy of food. Cal.	Average live-weight. Kgs.	Gain or loss of N. by body. Grms.	Nutritive ratio 1:
EXPERIMENT I:					
Steer 1,	129	7,956	420	—2.51	20.1
Steer 2,	113	7,588	450	—0.39	20.4
Steer 3,	133	7,191	400	—1.08	18.6
EXPERIMENT II:					
Steer 1,	192	8,144	420	1.76	13.4
Steer 2,	202	9,590	450	4.23	13.6
Steer 3,	209	8,084	400	4.62	12.8
EXPERIMENT VI:					
Steer 1,	297	11,130	450	4.67	10.8
Steer 2,	277	11,318	490	6.47	10.9
Steer 3,	314	11,324	430	2.65	10.5
EXPERIMENT VII:					
Steer 1,	156	11,955	450	5.68	23.0
Steer 2,	131	11,904	490	3.98	25.3
Steer 3,	152	11,557	430	4.15	23.9
EXPERIMENT VIII:					
Steer 1,	258	11,634	543	+0.26	10.4
Steer 2,	242	12,976	629	—0.20	10.7
Steer 3,	275	12,030	516	—2.31	10.6

The striking feature of these results is the remarkably small amount of proteids which seems to have sufficed to maintain nitrogen equilibrium. The minimum appears to have been reached in Experiment VII, with an average of only 146 grams per day and 500 kgs. This experiment was of short duration, however, and, as noted in the detailed account of it, there is some question as to the accuracy of the results as regards nitrogen. Next stands Experiment II, with an average of 201 grms. This experiment lasted 71 days, and while a considerable loss of weight resulted, there was no evidence of any physical disturbance of the organism, and there was an apparent gain of nitrogen sufficient, according to Henneberg and Stohmann's* results, to cover the demands for the growth of hair, epidermis, etc. Experiment VI, with an average of 296 grams of proteids, more total food and a narrower nutritive ratio, shows but slightly more gain of nitrogen than Experiment II, the larger supply of proteids resulting, as was to be expected, in an increased proteid metabolism. Experiment VIII, with somewhat less proteids than VI (258 grams), but otherwise quite similar to the latter, shows some loss of nitrogen from the body. It would appear then, that with a nutritive ratio of about 1:11, a minimum of about 300 grams of proteids per day and 500 kgs. live weight is required for maintenance and that any material dimunition of this amount will result in a loss from the body. Furthermore, however, it would appear that if the nutritive ratio be made wider, this amount of proteids may be very materially reduced, at least for a time, without leading to a loss of nitrogen by the body or to any recognizable injurious consequences.

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*Neue Beitrage, 1870, p. 446.

This conclusion accords with what we know of the functions of the non-nitrogenous nutrients and is supported also by the results of other investigators. Thus E. Voit & Korkunoff[*] found that the minimum of proteids required to maintain nitrogen-equilibrium, expressed as a percentage of the amount metabolized during hunger, decreases as the amount of fat or carbohydrates in the ration is increased, while Munk[†] claims that, with an abundant supply of non-nitrogenous nutrients, the proteids of the food may even be reduced below the amount metabolized during hunger, a claim which is, however, disputed by Voit. Gabriel,[‡] too, found that the proteid supply of a sheep on a maintenance ration could be temporarily reduced by over 20 per cent. without causing a loss of nitrogen from the body, while a similar dimunition of the non-nitrogenous nutrients changed a daily gain of 0.22 grms. nitrogen into a daily loss of 1.88 grms.

The figures on page 165 refer to proteids, that is, to proteid N (by Stutzer's method) x 6.25. The average amount of total nitrogenous matter (N x. 615) consumed per 500 kgs. in those of Kühn's and Kellner's experiments in which there was a gain of proteids by the animals was 366 grams (compare p. 24), which agrees well with the conclusions drawn from Experiments VI and VIII, while the nutritive ratio, calculated on the total nitrogenous matter was from 1:8.8 to 1:11.0. In three cases in which there was a loss of proteids by the body, the total digestible nitrogenous matter of the ration averaged 264 grams and the nutritive ratio 1:12. In one experiment, the total digestible nitrogenous matter was 213 grams and in spite of a wide nutritive ratio (1:19.8) there was a considerable loss of proteids by the animal. While, then, 300 grams of proteids per day and 500 kgs. live weight appears to be sufficient to fully maintain nitrogen-equilibrium for a considerable period, some doubt is cast upon the results of Experiments II and VII, in which much smaller amounts appeared to suffice for this purpose, and pending further experiments, it is probably safer to regard the amount above stated as the minimum.

Whether this quantity would prove permanently sufficient for maintenance, however, may perhaps be questioned. Munk[§] and Rosenheim[‖] have shown that a ration poor in proteids may maintain an animal substantially unchanged in weight and without loss of proteids and yet produce profound functional disturbances and finally death. There appear to be no similar experiments on herbivorous animals and hence no data by which to judge of the sufficiency of the above ration in this respect.

Finally it may not be superfluous to point out that the term proteids as here employed, following the common usages, is a conventional term. Neither the variations in the percentage of nitrogen in the vegetable proteids nor the presence of nitrogenous metabolic products in the feces have been taken account of. As regards the former, our knowledge of the composition of the proteids of coarse fodders is insufficient to enable us to substitute any other factor for the conventional 6.25, so that only in one experiment (VIII) was there any approximately sufficient basis for a re-calculation of the analytical results.

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[*] Zeit. f. Biol., 32, 59.

Arch. ges. Physiol., 61, 607; Jahresb. Agr. Ch., N. F., 18, 423.

Jour. f. Landw., 40, 293.

[§] Jahresb. Thier Chem., 21, 365.

[‖] Archiv. ges. Physiol., 54, 61.

The metabolic products in the feces can be determined with some degree of accuracy, but inasmuch as they are waste products, it makes little practical difference in any single experiment of this sort whether we correct the apparent digestibility of the proteids for them in order to obtain the true percentage digestibility and say that the ration contained e. g. 325 grams of digestible proteids, of which 25 grams was required to make good the excretion of metabolic products in the feces, or whether we subtract the total proteids of the feces from those of the food and say that the ration contained the net amount of 300 grams of proteids available to the body.

In the case of widely different rations, of course, the proportion of metabolic products may vary and thus distort the comparison and undoubtedly their determination is desirable, but it is not believed that the failure to take account of them in these experiments seriously affects the value of the results as regards proteids, while, as already pointed out, the results on the energy of the rations are independent of it.

APPENDIX.

Experiments of 1894-5.

DAILY RESULTS.

Steer No. 1.

	Live weight. Kgs.	Water drunk. Kgs.	Feces.					Urine.		
			Weight. Grams.	Air-dry Weight.		Nitrogen.		Weight. Grams.	Nitrogen.	
				Per cent.	Weight. Grms.	Per cent. in air-dry matter.	Weight. Grams.		Per cent.	Weight. Grams.
November 28, 1894, ...	441.8	13.2	12,112	20.67	2,504	1.780	44.57	....	....	....
November 29, 1894, ...	440.0	13.6	11,594	22.42	2,600	1.695	44.07	4,820	0.923	44.49
November 30, 1894, ...	440.0	19.1	13,580	21.32	2,895	1.695	49.07	6,676	0.887	59.22
December 1, 1894, ...	434.5	11.8	12,691	21.26	2,698	1.720	46.41	6,721	0.931	62.57
December 2, 1894, ...	444.1	28.1	13,405	19.40	2,601	1.665	43.31	5,046	1.103	55.66
December 3, 1894, ...	426.8	0.9	....	....	....	....	....	....	....	....
December 4, 1894, ...	439.1	28.6	....	....	....	....	....	....	....	....
December 5, 1894, ...	442.7	20.0	14,560	21.24	3,093	1.485	45.94	5,291	0.980	51.85
December 6, 1894, ...	449.1	23.1	13,007	20.77	2,702	1.510	40.80	5,093	1.004	51.13
December 7, 1894, ...	437.7	5.4	13,508	20.74	2,801	1.555	43.56	5,242	0.984	51.58
December 8, 1894, ...	445.0	25.4	12,880	18.60	2,396	1.450	34.74	6,786	0.791	53.68
December 9, 1894, ...	442.3	18.1	14,245	19.01	2,708	1.470	39.81	5,641	0.848	47.84
December 10, 1894, ...	443.2	18.6	13,230	17.70	2,342	1.550	36.30	5,695	0.939	53.48
December 11, 1894, ...	445.0	19.1	13,734	18.97	2,605	1.485	38.69	4,920	0.950	46.74
December 12, 1894, ...	438.6	13.6	13,476	18.51	2,494	1.470	36.66	7,506	0.655	49.16
December 13, 1894, ...	452.7	25.0	11,769	18.65	2,195	1.660	36.44	5,781	0.710	41.04
December 14, 1894, ...	447.7	14.1	....	....	....	....	....	....	....	....
December 15, 1894, ...	446.8	16.8	13,342	18.80	2,509	1.490	37.39	6,123	0.738	45.19
December 16, 1897, ...	452.7	22.7	....	....	....	....	....	....	....	....
December 17, 1894, ...	448.6	15.4	....	....	....	....	....	....	....	....
December 18, 1894, ...	447.3	16.8	14,119	17.73	2,503	1.470	36.80	6,058	0.695	42.10
December 19, 1894, ...	450.9	21.8	11,734	18.80	2,208	1.450	32.02	6,361	0.708	45.04
December 20, 1894, ...	448.2	14.5	12,695	18.90	2,399	1.410	33.83	5,968	0.717	42.79
December 21, 1894, ...	450.9	20.9	12,930	18.60	2,405	1.46	35.11	5.984	0.701	41.95
December 22, 1894, ...	452.7	17.7	10,098	18.81	1,900	1.48	28.12	5,443	0.830	45.17
December 23, 1894, ...	447.7	15.0	12,810	19.53	2,502	1.63	40.80	6,515	0.750	48.86
December 24, 1894, ...	449.1	19.1	13,594	19.11	2,597	1.53	39.74	5,457	0.731	39.89
December 25, 1894, ...	451.8	20.0	12,588	18.25	2,298	1.48	34.01	6,431	0.669	43.02
December 26, 1894, ...	447.7	16.3	13,587	17.64	2,397	1.52	36.44	8,709	0.520	45.29

December 27, 1894, ...	450.5	24.0	14,066	19.14	2,690	1.49	40.08	7,724	0.504	33.93
December 28, 1894, ...	443.6	13.2	12,539	20.00	2,508	1.43	35.87	8,751	0.457	39.99
December 29, 1894, ...	449.6	23.1	12,817	19.53	2,508	1.49	37.33	6,221	0.528	32.85
December 30, 1894, ...	448.2	14.5	11,944	19.33	2,309	1.53	35.33	5,660	0.613	34.70
December 31, 1894, ...	446.4	14.5	11,483	19.13	2,197	1.48	32.52	5,990	0.724	43.37
January 1, 1895, ...	450.2	21.8	11,406	20.17	2,301	1.49	34.29	8,254	0.521	43.01
January 2, 895, ...	454.2	22.4	13,650	18.97	2,590	1.45	37.55	5,725	0.69	39.50
January 3, 1895, ...	452.6	15.2	12,136	19.01	2,805	1.45	33.42	5,436	0.81	44.03
January 4, 1895, ...	453.0	18.6	13,545	18.51	2,507	1.45	36.35	5,990	0.82	49.12
January 5, 1895, ...	456.0	17.2	10,932	18.35	3,006	1.50	30.09	5,009	0.82	41.08
January 6, 1895, ...	452.8	16.2	14,636	19.86	2,907	1.52	44.19	5,977	0.73	43.63
January 7, 1895, ...	451.0	19.2	14,146	17.73	2,508	1.46	36.62	5,855	0.74	43.33
January 8, 1895, ...	444.4	13.2	13,699	17.52	2,400	1.49	35.76	7,158	0.66	47.24
January 9, 1895, ...	451.6	27.0	14,860	16.11	2,394	1.43	34.24	6,597	0.63	41.56
January 10, 1894, ...	448.6	18.8	16,915	15.98	2,703	1.48	40.01	6,515	0.64	41.70
January 11, 1895, ...	452.2	20.6	12,825	17.97	2,306	1.57	36.19	7,450	0.55	40.98
January 12, 1895, ...	452.4	23.2	14,413	18.05	2,602	1.50	39.03	7,249	0.55	39.87
January 13, 1895, ...	446.2	12.8	13,958	18.57	2,592	1.45	37.58	6,478	0.65	42.10
January 14, 1895, ...	448.2	20.8	....	....	....	....	....	....	....	....
January 15, 1895, ...	450.6	19.6	13,818	17.39	2,403	1.56	37.49	6,080	0.69	41.60
January 16, 1895, ...	450.6	17.0	13,084	18.32	2,397	1.53	36.68	5,501	0.69	37.96
January 17, 1895, ...	451.2	21.2	15,098	17.22	2,600	1.53	39.78	6,450	0.68	43.86
January 18, 1895, ...	448.0	16.3	15,238	16.45	2,507	1.49	37.36	7,339	0.61	45.07
January 19, 1895, ...	452.2	22.6	12,846	17.19	2,208	1.48	32.68	7,604	0.59	44.86
January 20, 1895, ...	451.0	18.8	14,280	17.48	2,496	1.48	35.69	6,837	0.59	40.34
January 21, 1895, ...	453.0	21.8	12,000	17.50	2,100	1.52	31.92	....	....	....
January 22, 1895, ...	454.2	20.8	14,070	17.02	2,395	1.53	36.41	6,844	0.56	38.33
January 23, 1895, ...	446.2	8.8	13,291	18.04	2,398	1.49	35.73	6,200	0.67	41.54
January 24, 1895, ...	449.0	20.4	13,012	16.92	2,202	1.55	34.13	5,939	0.70	41.57
January 25, 1895, ...	446.4	14.6	13,546	15.56	2,108	1.57	33.10	5,870	0.72	42.26
January 26, 1895, ...	445.4	16.5	....	....	....	....	35.68	6,411	0.69	44.23
January 27, 1895, ...	443.4	17.3	14,296	17.49	2,500	1.53	38.25	....	....	....
January 28, 1895, ...	448.6	22.6	14,494	17.25	2,600	1.55	38.75	6,129	0.60	36.77
January 29, 1895, ...	447.2	16.4	13,664	18.25	2,494	1.53	38.16	6,315	0.66	41.68
January 30, 1895, ...	450.0	20.6	12,305	17.89	2,202	1.52	33.47	5,391	0.70	37.74
January 31, 1895, ...	450.8	18.2	13,436	19.41	2,608	1.57	40.95	....	....	....
February 1, 1895, ...	448.6	14.6	12,442	17.75	2,209	1.58	34.91	5,979	0.75	44.84
February 2, 1895, ...	452.6	20.0	12,396	18.55	2,300	1.46	33.58	5,810	0.70	40.67
February 3, 1895, ...	454.2	21.4	15,259	19.00	2,899	1.53	44.36	6,179	0.70	43.25
February 4, 1895, ...	446.8	1.6	14,384	18.49	2,650	1.56	41.34	5,440	0.73	39.71
February 5, 1895, ...	452.2	22.9	13,064	19.00	2,482	1.53	37.98	7,029	0.68	47.80
February 6, 1895, ...	449.0	15.0	12,756	22.50	2,870	1.37	39.61	6,790	0.71	48.21
February 7, 1895, ...	458.6	27.8	12,889	18.50	2,385	1.53	36.49	5,909	0.65	38.41
February 8, 1895, ...	449.4	9.4	13,356	18.00	2,404	1.53	36.78	6,003	0.73	43.82
February 9, 1895, ...	452.0	18.2	11,949	18.00	2,151	1.65	35.49	6,618	0.67	44.34
February 10, 1895, ...	460.4	25.4	13,936	19.25	2,683	1.50	40.25	5,210	0.81	42.20
February 11, 1895, ...	455.6	14.2	11,804	17.75	2,095	1.46	30.59	6,829	0.77	52.58
February 12, 1895, ...	459.0	24.4	13,336	18.00	2,401	1.45	34.82	6,065	0.73	44.27
February 13, 1895, ...	460.4	21.0	14,144	18.00	2,546	1.48	37.68	6,337	0.72	45.68
February 14, 1895, ...	461.6	22.8	15,186	20.50	3,113	1.50	46.70	6,765	0.64	43.30
February 15, 1895, ...	446.2	3.0	13,054	18.75	2,448	1.49	36.48	7,816	0.615	43.07
February 16, 1895, ...	454.8	26.9	....	....	....	....	....	....	....	....
February 17, 1895, ...	435.0	2.2	....	....	....	....	....	....	....	....
February 18, 1895, ...	447.8	39.9	....	....	....	....	....	....	....	....
February 19, 1895, ...	449.2	21.0	....	....	....	....	....	....	....	....

Steer No. 1—Continued.

	Live weight. Kgs.	Water drunk. Kgs.	Fæces.					Urine.		
			Weight. Grams.	Air-dry Weight.		Nitrogen.		Weight. Grams.	Nitrogen.	
				Per cent.	Weight. Grms.	Per cent. in air-dry matter.	Weight. Grams.		Per cent.	Weight. Grams.
February 20, 1895,	451.2	21.8	....	....	....	....	....	....	....	....
February 21, 1895,	448.2	15.0	....	....	....	....	....	....	....	....
February 22, 1895,	449.6	17.2	....	....	....	....	....	....	....	....
February 23, 1895,	451.0	17.6	....	....	....	....	....	....	....	....
February 24, 1895,	447.4	15.8	....	....	....	....	....	....	....	....
February 25, 1895,	446.4	17.0	....	....	....	....	....	....	....	....
February 26, 1895,	432.4	4.2	....	....	....	....	....	....	....	....
February 27, 1895,	438.8	23.6	....	....	....	....	....	....	....	....
February 28, 1895,	458.7	36.0	....	....	....	....	....	....	....	....
March 1, 1895,	451.4	10.9	....	....	....	....	....	....	....	....
March 2, 1895,	454.0	19.6	....	....	....	....	....	....	....	....
March 3, 1895,	453.6	16.6	....	....	....	....	....	....	....	....
March 4, 1895,	438.2	1.0	....	....	....	....	....	....	....	....
March 5, 1895,	446.6	34.0	....	....	....	....	....	....	....	....
March 6, 1895,	449.0	21.0	12,846	20.75	2,666	1.36	36.26	5,329	0.75	39.97
March 7, 1895,	453.0	21.9	13,357	20.75	2,772	1.39	38.53	5,270	0.90	47.43
March 8, 1895,	455.4	19.2	11,616	19.50	2,265	1.52	34.43	5,889	0.77	45.34
March 9, 1895,	453.0	14.8	11,744	20.25	2,378	1.48	35.20	5,480	0.79	43.29
March 10, 1895,	456.8	20.0	11,846	20.25	2,399	1.55	37.19	5,339	0.80	42.71
March 11, 1895,	458.4	18.2	11,554	18.50	2,138	1.60	34.21	5,500	0.77	42.35
March 12, 1895,	455.6	16.0	13,247	18.50	24.51	1.50	36.77	6,659	0.62	41.29
March 13, 1895,	455.6	18.4	13,444	18.00	2,420	1.53	37.03	6,080	0.66	40.13
March 14, 1895,	453.8	15.4	12,756	19.50	2,487	1.43	35.56	....	....	....
March 15, 1895,	454.2	18.6	13,314	18.50	2,463	1.45	35.72	6,060	0.61	36.96
March 16, 1895,	454.6	19.0	14,306	18.50	2,647	1.49	39.44	6,189	0.58	35.90
March 17, 1895,	449.0	11.0	11,694	17.17	2,008	1.50	30.12	6,987	0.48	33.54
March 18, 1895,	451.6	18.2	10,756	17.67	1,901	1.46	27.75	7,029	0.45	31.63
March 19, 1895,	451.6	15.8	11,146	18.00	2,006	1.50	30.09	7,110	0.46	32.71
March 20, 1895,	450.0	15.8	10,358	18.33	1,899	1.59	30.20	5,966	0.55	32.81
March 21, 1895,	448.0	13.6	11,654	17.33	2,020	1.53	30.91	6,930	0.48	33.26
March 22, 1895,	448.2	16.4	12,126	18.33	2,223	1.46	32.46	6,729	0.49	32.97
March 23, 1895,	446.7	17.6	12,172	18.33	2,231	1.53	34.14	8,400	0.44	36.96
March 24, 1895,	451.9	23.9	11,935	18.00	2,149	1.52	32.67	6,626	0.46	30.48
March 25, 1895,	448.2	13.0	11,854	18.00	2,134	1.49	31.80	6,600	0.48	31.68
March 26, 1895,	445.8	11.6	9,526	18.33	1,746	1.57	27.42	5,939	0.52	30.88
March 27, 1895,	450.0	18.2	9,194	21.83	2,007	1.52	30.51	5,920	0.58	34.34
March 28, 1895,	452.4	15.0	9,214	19.33	1,781	1.59	28.32	5,289	0.57	30.15
March 29, 1895,	450.8	14.4	11,294	19.50	2,202	1.49	32.81	4,850	0.53	25.70
March 30, 1895,	448.3	10.6	10,336	19.50	2,016	1.41	28.43	6,099	0.35	21.35

March 31, 1895,	456.8	22.2	9,224	20.33	1,875	1.38	26.88	5,720	0.44	25.17
April 1, 1895,	452.0	11.3	9,896	19.67	1,947	1.41	27.45	6,269	0.43	26.96
April 2, 1895,	450.0	15.0	10,904	18.67	2,063	1.42	29.15	5,780	0.42	24.28
April 3, 1895,	453.0	15.0	9,266	20.00	1,853	1.35	25.02	5,500	0.45	24.75
April 4, 1895,	453.0	17.0	12,024	19.00	2,285	1.29	29.48	7,176	0.36	25.82
April 5, 1895,	450.4	17.0	10,901	19.83	2,162	1.28	27.67	8,109	0.31	25.14
April 6, 1895,	453.4	19.6	10,634	19.83	2,109	1.31	27.63	8,340	0.31	25.86
April 7, 1895,	450.6	14.8	10,396	19.33	2,010	1.43	28.54	6,289	0.36	22.64
April 8, 1895,	456.0	19.4	10,114	19.67	1,989	1.28	27.45	5,260	0.41	21.53
April 9, 1895,	452.2	14.2	10,084	19.67	1,984	1.45	28.77	6,579	0.41	26.97
April 10, 1895,	452.8	17.4	9,434	19.67	1,856	1.39	25.80	8,370	0.36	30.13
April 11, 1895,	454.4	19.0	11,886	18.67	2,219	1.28	28.40	5,799	0.43	24.94
April 12, 1895,	455.2	14.0	9,716	19.00	1,846	1.35	24.92	......	......	......
April 13, 1895,	453.9	12.8	10,936	18.57	2,031	1.43	28.84	5,397	0.49	26.45
April 14, 1895,	457.0	20.3	11,574	18.75	2,170	1.42	30.81	5,690	0.47	26.74
April 15, 1895,	454.2	11.2	8,876	19.10	1,695	1.42	24.07	7,879	0.36	28.37
April 16, 1895,	450.8	14.6	12,734	19.29	2,457	1.38	33.91	7,370	0.36	26.53
April 17, 1895,	445.8	13.2	12,316	18.29	2,253	1.27	28.61	6,449	0.37	23.86
April 18, 1895,	452.4	19.3	9,544	17.62	1,682	1.31	22.03	4,885	0.39	19.05
April 19, 1895,	450.2	13.2	10,366	20.19	2,093	1.29	27.00	4,411	0.43	18.97
April 20, 1895,	452.0	15.8	10,364	20.00	2,073	1.31	27.16	3,700	0.50	18.50
April 21, 1895,	454.2	18.5	10,181	21.00	2,138	1.29	27.58	5,479	0.44	24.11
April 22, 1895,	453.3	25.2	10,444	20.00	2,089	1.22	25.49	4,780	0.41	19.60
April 23, 1895,	452.9	14.9	10,156	19.67	1,998	1.24	24.78	5,184	0.42	21.77
April 24, 1895,	......	13.9	......	......						

Steer No. 2.

November 28, 1894,	492.6	20.4	10,091	22.77	2,298	1.745	40.10	5,612	.923	51.80
November 29, 1894,	482.2	5.4	11,504	23.48	2,702	1.710	46.21	5,450	0.804	43.82
November 30, 1894,	494.0	27.7	10,972	24.55	2,694	1.770	47.69	6,542	0.750	49.07
December 1, 1894,	490.8	15.9	12,301	21.95	2,700	1.835	49.28	......	......	......
December 2, 1894,	485.4	15.0	11,140	22.52	2,509	1.710	42.91	......	......	......
December 3, 1894,	492.6	16.8	12,133	21.49	2,608	1.620	42.25	6,072	0.902	54.77
December 4, 1894,	480.4	6.8	14,035	20.71	2,907	1.565	45.50	......	......	......
December 5, 1895,	493.5	26.3	9.412	20.21	1,902	1.510	28.72	......	......	......
December 6, 1894,	490.4	14.1	12,280	22.77	2,796	1.565	43.76	6,213	0.706	43.86
December 7, 1894,	491.7	18.1	10,748	22.43	2,411	2.045	49.31	5,548	0.869	48.21
December 8, 1895,	489.5	14.5	10,574	21.70	2,295	1.735	39.82	6,423	0.925	59.41
December 9, 1894,	492.2	19.1	11,042	21.82	2,409	1.470	35.41	......	......	......
December 10, 1894,	493.5	20.0	10,706	20.57	2,202	1.570	34.57	7,723	0.762	58.85
December 11, 1894,	492.6	18.6	12,762	20.32	2,593	1.540	39.93	6,856	0.795	54.51
December 12, 1894,	483.5	11.3	14,881	20.81	3,097	1.530	47.39	6,234	0.780	48.63
December 13, 1894,	494.0	25.0	9,328	20.43	1,906	1.620	30.88	6,849	0.700	47.93
December 14, 1894,	493.5	18.1	12,980	20.00	2,596	1.595	41.41	5,591	0.660	36.90
December 15, 1894,	490.8	18.1	13,965	20.00	2,793	1.570	43.85	......	......	......
December 16, 1894,	491.3	18.1	10,671	18.69	1,994	1.440	28.71	5,913	0.710	41.98
December 17, 1894,	490.4	19.5	13,573	20.59	2,795	1.540	43.05	7,066	0.656	46.36
December 18, 1894,	489.9	16.8	12,280	20.33	2,497	1.560	38.96	5,984	[illegible]	39.70
December 19, 1894,	492.2	18.6	10,769	20.37	2,194	1.570	34.45	6,471	0.645	41.74
December 20, 1894,	490.8	16.8	12,000	19.17	2,300	1.590	36.57	6,871	0.608	41.86

Steer No. 2—Continued.

	Live weight. Kgs.	Water drunk. Kgs.	Feces.					Urine.		
			Weight. Grams.	Air-dry Weight.		Nitrogen.		Weight. Grams.	Nitrogen.	
				Per cent.	Weight. Grms.	Per cent. in air-dry matter.	Weight. Grams.		Per cent.	Weight. Grams.
December 21, 1894,	492.6	21.3	12,796	18.53	2,371	1.57	37.22	6,835	0.567	38.75
December 22, 1894,	477.2	17.7	12,140	19.84	2,409	1.55	37.34	6,738	0.604	40.70
December 23, 1894,	488.5	20.0	15,923	18.86	3,003	1.53	45.95	6,730	0.603	40.58
December 24, 1894,	496.3	23.6	10,476	18.10	1,896	1.55	29.39	5,836	0.631	36.83
December 25, 1894,	495.8	18.6	12,719	18.90	2,404	1.59	38.22	6,639	0.634	42.09
December 26, 1894,	492.2	15.9	11,931	18.49	2,206	1.52	33.53	7,387	0.612	45.21
December 27, 1894,	494.0	20.4	12,427	19.36	2,406	1.50	36.09	6,051	0.604	36.55
December 28, 1894,	494.5	18.6	11,196	20.54	2,300	1.59	36.57	7,282	0.543	39.54
December 29, 1894,	495.8	20.4	11,923	20.17	2,405	1.52	36.56	6,485	0.567	36.77
December 30, 1894,	490.4	12.2	12,672	19.78	2,507	1.55	38.86	6,060	0.582	35.27
December 31, 1894,	495.4	24.5	12,950	21.54	2,789	1.52	42.40	6,828	0.521	35.57
January 1, 1895,	495.8	19.1	11,294	20.36	2,300	1.48	34.04	7,212	0.575	41.47
January 2, 1895,	488.2	11.2	12,740	22.05	2,809	1.49	41.86	6,548	0.55	36.01
January 3, 1895,	497.2	25.2	10,147	19.80	2,009	1.56	31.34	6,367	0.60	38.20
January 4, 1895,	494.2	15.2	12,469	20.00	2,494	1.53	38.16	6,247	0.64	39.98
January 5, 1895,	498.0	19.4	10,140	18.81	1,907	1.55	29.56	5,863	0.68	39.87
January 6, 1895,	495.0	14.6	11,727	20.51	2,406	1.55	37.28	6,513	0.74	48.20
January 7, 1895,	497.2	20.8	12,560	19.84	2,492	1.52	37.88	5,863	0.71	41.63
January 8, 1895,	480.8	1.0	10,629	18.87	2,006	1.59	31.90	6,911	0.63	43.54
January 9, 1895,	494.0	26.8	7,860	20.25	1,592	1.62	25.79	5,689	0.62	35.27
January 10, 1895,	504.4	28.2	12,609	19.05	2,402	1.45	34.83	5,848	0.70	40.94
January 11, 1895,	498.6	16.2	14,749	21.09	3,111	1.55	48.22	6,612	0.79	52.24
January 12, 1895,	498.8	18.7	12,077	18.18	2,196	1.46	32.06	6,443	0.74	47.68
January 13, 1895,	498.0	18.0	14,756	18.92	2,792	1.45	40.48	5,654	0.74	41.84
January 14, 1895,	496.6	15.2	10,657	19.63	2,092	1.55	32.43	6,121	0.64	39.17
January 15, 1895,	499.0	20.4	12,630	19.05	2,406	1.46	35.13	6,535	0.68	44.43
January 16, 1895,	499.8	18.6	11,937	21.01	2,508	1.52	38.12	6,765	0.64	43.30
January 17, 1895,	481.8	1.0	13,336	19.55	2,607	1.48	38.59	6,339	0.68	43.10
January 18, 1895,	492.9	28.8	11,712	18.80	2,202	1.53	33.69	....	....	....
January 19, 1895,	502.2	25.3	11,692	19.66	2,299	1.52	34.95	5,151	0.58	29.88
January 20, 1895,	498.8	14.4	11,349	20.00	2,270	1.49	33.83	6,821	0.76	51.84
January 21, 1895,	499.4	15.4	9,706	20.62	2,001	1.43	28.61	5,416	0.68	36.83
January 22, 1895,	501.0	19.6	11,475	20.00	2,295	1.49	34.20	6,471	0.68	44.00
January 23, 1895,	500.4	18.0	13,184	19.70	2,598	1.53	39.75	6,123	0.70	42.86
January 24, 1895,	493.6	10.8	11,081	22.53	2,497	1.49	37.21	7,331	0.61	44.72
January 25, 1895,	500.2	22.4	11,064	20.72	2,293	1.49	34.17	5,745	0.57	32.75
January 26, 1895,	501.8	19.0	11,921	20.17	2,406	1.53	36.80	6,561	0.58	38.05
January 27, 1895,	498.6	16.4	13,663	19.71	2,693	1.48	39.86	6,373	0.62	39.51
January 28, 1895,	497.4	14.6	10,401	20.20	2,101	1.46	30.68	6,291	0.68	42.78

January 29, 1895,	493.6	12.8	11,374	21.06	2,395	1.49	35.69	6,673	0.62	41.37
January 30, 1895,	504.4	26.0	9,821	26.53	2,606	1.60	41.70	5,904	0.63	37.20
January 31, 1895,	499.0	12.7	11,714	22.23	2,604	1.56	40.63	6,583	0.66	43.45
February 1, 1895,	494.2	12.3	12,401	21.78	2,701	1.53	41.33	6,831	0.61	41.67
February 2, 1895,	505.2	26.4	9,974	21.00	2,095	1.50	31.43	5,403	0.73	39.44
February 3, 1895,	500.0	12.6	12,799	22.00	2,816	1.52	42.81	5,551	0.70	38.86
February 4, 1895,	499.0	15.2	9,702	21.00	2,037	1.50	30.56	7,123	0.72	51.28
February 5, 1895,	502.2	18.4	10,931	20.50	2,241	1.49	33.39	5,521	0.70	38.65
February 6, 1895,	493.4	9.2	12,164	16.00	1,946	1.55	30.17	6,533	0.55	35.93
February 7, 1895,	503.0	26.2	10,691	21.00	2,245	1.55	34.80	5,226	0.80	41.81
February 8, 1895,	500.4	13.0	10,814	20.50	2,217	1.53	33.92	5,160	0.74	38.18
February 9, 1895,	499.0	17.4	12,626	19.50	2,462	1.60	39.40	7,021	0.70	49.15
February 10, 1895,	500.4	19.6	10,794	19.50	2,105	1.45	30.53	....	....	....
February 11, 1895,	490.2	11.0	13,731	22.00	3,021	1.41	42.62	5,911	0.71	41.97
February 12, 1895,	511.0	37.2	9,594	19.00	1,823	1.49	27.16	6,403	0.75	48.02
February 13, 1895,	494.0	1.0	10,851	17.50	1,899	1.49	28.30	5,861	0.84	49.24
February 14, 1895,	506.6	30.4	12,616	19.00	2,397	1.53	36.68	6,383	0.81	51.90
February 15, 1895,	493.4	6.0	14,711	20.25	2,979	1.46	43.50	6,021	0.83	49.97
February 16, 1895,	500.4	25.2	....	....	....	....	....	....	....	....
February 17, 1895,	483.4	1.0	....	....	....	....	....	....	....	....
February 18, 1895,	498.4	31.2	....	....	....	....	....	....	....	....
February 19, 1895,	492.6	13.0	....	....	....	....	....	....	....	....
February 20, 1895,	499.2	21.8	....	....	....	....	....	....	....	....
February 21, 1895,	482.4	1.0	....	....	....	....	....	....	....	....
February 22, 1895,	504.0	36.0	....	....	....	....	....	....	....	....
February 23, 1895,	488.9	1.0	....	....	....	....	....	....	....	....
February 24, 1895,	499.8	26.7	....	....	....	....	....	....	....	....
February 25, 1895,	492.2	11.0	....	....	....	....	....	....	....	....
February 26, 1895,	490.4	15.2	....	....	....	....	....	....	....	....
February 27, 1895,	494.8	22.2	....	....	....	....	....	....	....	....
February 28, 1895,	496.3	16.6	....	....	....	....	....	....	....	....
March 1, 1895,	479.2	1.0	....	....	....	....	....	....	....	....
March 2, 1895,	491.4	25.6	....	....	....	....	....	....	....	....
March 3, 1895,	502.2	25.2	....	....	....	....	....	....	....	....
March 4, 1895,	485.4	1.0	....	....	....	....	....	....	....	....
March 5, 1895,	493.2	25.6	....	....	....	....	....	....	....	....
March 6, 1895,	493.6	15.8	11,034	21.00	2,317	1.49	34.53	5,101	0.83	42.34
March 7, 1895,	498.4	20.4	10,921	19.75	2,157	1.49	32.14	5,278	0.93	49.09
March 8, 1895,	498.6	16.2	10,634	19.00	2,021	1.53	30.92	5,851	0.85	49.73
March 9, 1895,	497.6	17.0	12,571	22.00	2,766	1.57	43.43	5,143	0.77	39.60
March 10, 1895,	495.2	14.6	10,724	21.00	2,252	1.52	34.23	7,251	0.71	51.48
March 11, 1895,	500.0	22.2	12,241	20.00	2,448	1.57	38.44	4,891	0.74	36.19
March 12, 1895,	498.6	14.6	11,024	20.00	2,205	1.55	34.18	6,011	0.77	46.28
March 13, 1895,	497.0	13.4	10,001	18.83	1,883	1.60	30.13	5,241	0.74	38.78
March 14, 1895,	482.8	1.0	11,044	20.33	2,245	1.50	33.68	5,441	0.72	39.17
March 15, 1895,	495.6	26.6	10,191	21.33	2,174	1.55	33.70	5,383	0.62	33.37
March 16, 1895,	504.4	24.4	12,194	18.83	2,296	1.56	35.82	....	....	....
March 17, 1895,	502.4	19.2	15,681	17.67	2,771	1.49	41.29	....	....	....
March 18, 1895,	495.0	10.2	11,560	18.00	2,081	1.59	33.09	7,431	0.52	38.64
March 19, 1895,	480.6	1.0	10,111	18.33	1,853	1.57	29.09	6,825	0.45	30.71
March 20, 1895,	500.0	31.6	8,334	19.00	1,584	1.66	26.30	....	....	....
March 21, 1895,	501.4	19.2	13,241	18.00	2,383	1.57	37.41	5,323	0.52	27.68
March 22, 1895,	497.4	17.0	12,874	17.00	2,189	1.53	33.49	7,931	0.52	41.24
March 23, 1895,	495.8	15.0	9,871	18.17	1,794	1.59	28.53	7,933	0.41	32.53
March 24, 1895,	495.4	18.6	10,294	18.00	1,853	1.53	28.35	....	....	....

Steer No. 2—Continued.

	Live weight. Kgs.	Water drunk. Kgs.	Feces.					Urine.		
			Weight. Grams.	Air-dry Weight.		Nitrogen.		Weight. Grams.	Nitrogen.	
				Per cent.	Weight. Grms.	Per cent. in air-dry matter.	Weight. Grams.		Per cent.	Weight. Grams.
March 25, 1895,	497.0	18.0	11,791	18.00	2,123	1.55	32.91	6,163	0.41	25.27
March 26, 1895,	491.2	14.4	10,044	18.33	1,841	1.50	27.62	....	....	....
March 27, 1895,	494.0	17.2	7,023	22.67	1,592	1.48	23.56	8,013	0.37	29.65
March 28, 1895,	493.8	16.8	10,474	20.17	2,113	1.55	32.75	6,831	0.42	28.69
March 29, 1895,	492.6	13.6	9,851	20.00	1,970	1.56	30.73	6,183	0.45	27.82
March 30, 1895,	492.2	14.6	10,444	20.67	2,159	1.49	32.17	6,146	0.45	27.66
March 31, 1895,	498.1	25.9	9,481	20.67	1,960	1.45	28.42	....	....	....
April 1, 1895,	497.4	14.1	9,464	19.17	1,814	1.35	24.49	5,461	0.37	20.21
April 2, 1895,	497.4	15.8	10,771	19.67	2,119	1.56	33.06	6,193	0.39	24.15
April 3, 1895,	4,972	14.2	11,262	20.00	2,252	1.45	32.66	3,771	0.46	17.35
April 4, 1895,	493.4	10.8	9,889	19.83	1,961	1.42	27.85	5,786	0.49	28.35
April 5, 1895,	500.6	21.8	9,712	21.00	2,040	1.35	27.54	5,301	0.38	20.15
April 6, 1895,	496.0	13.4	12,081	20.00	2,416	1.34	32.38	6,333	0.37	23.43
April 7, 1895,	495.8	18.2	10,929	19.67	2,150	1.43	30.75	8,351	0.36	30.07
April 8, 1895,	493.0	13.8	9,181	21.00	1,929	1.42	27.39	7,273	0.35	25.46
April 9, 1895,	498.0	19.2	9,244	20.00	1,849	1.42	26.26	5,361	0.45	24.13
April 10, 1895,	495.4	12.0	14,051	20.33	2,857	1.41	40.28	3,816	0.52	19.84
April 11, 1895,	495.4	14.8	10,182	21.67	2,206	1.41	31.10	5,971	0.45	26.87
April 12, 1895,	499.2	15.8	8,041	20.00	1,608	1.39	22.35	4,883	0.50	24.42
April 13, 1895,	494.6	10.6	10,449	19.71	2,060	1.42	29.25	5,471	0.54	29.54
April 14, 1895,	503.6	23.8	12,481	19.60	2,446	1.39	34.00	4,133	0.57	23.56
April 15, 1895,	497.8	7.8	8,684	19.54	1,697	1.49	25.29	6,521	0.63	41.08
April 16, 1897,	499.6	15.8	11,171	19.20	2,145	1.43	30.67	4,823	0.49	23.63
April 17, 1895,	487.8	0.0	9,154	19.84	1,816	1.38	25.06	....	....	....
April 18, 1895,	496.2	24.4	12,981	19.61	2,546	1.39	35.39	4,013	0.56	22.47
April 19, 1895,	500.7	15.0	8,324	19.88	1,655	1.41	23.34	3,259	0.61	19.88
April 20, 1895,	494.0	6.3	9,551	21.33	2,037	1.43	29.13	4,053	0.58	23.51
April 21, 1895,	495.4	14.2	8,424	20.50	1,727	1.42	24.52	3,411	0.58	19.78
April 22, 1895,	500.4	18.0	9,569	20.83	1,993	1.41	28.10	3,735	0.53	19.80
April 23, 1895,	496.0	11.3	10,424	20.00	2,085	1.41	29.40	4,081	0.49	20.00
April 24, 1895,	....	14.0	....	....						

Steer No. 3.

November 28, 1894,	429.6	19.1	16,000	19.38	3,101	1.750	54.27	....	....	....
November 29, 1894,	423.2	15.0	16,196	19.13	3,098	1.690	52.36	7,231	0.668	48.30
November 30, 1894,	430.0	28.1	14,791	19.59	2,898	1.660	48.11	7,396	0.664	49.11
December 1, 1894,	424.1	15.0	14,560	19.85	2,890	1.705	49.28	....	....	....
December 2, 1894,	430.0	27.2	14,944	18.79	2,808	1.550	43.53	6,201	0.824	51.10
December 3, 1894,	413.7	1.0	12,035	19.86	2,390	1.553	37.12	6,924	0.719	49.78
December 4, 1894,	426.4	28.1	11,804	20.34	2,401	1.455	34.94	4,823	0.894	43.12
December 5, 1894,	430.0	22.2	12,980	20.00	2,596	1.595	41.41	....	....	....
December 6, 1894.	432.7	20.0	13,187	19.70	2,598	1.660	43.13	5,935	0.912	54.13
December 7, 1894,	424.6	11.3	13,426	19.40	2,605	1.585	41.29	4,825	0.935	45.11
December 8, 1894,	429.1	23.6	12,595	19.05	2,399	1.430	34.31	6,467	0,869	56.20
December 9, 1894,	429.1	20.9	15,371	17.53	2,695	1.760	47.43	6,658	0,836	55.66
December 10, 1894,	424.6	15.9	13,629	17.64	2,404	1.420	34.38	6,320	0.860	54.35
December 11, 1894,	424.1	15.9	12,385	17.74	2,197	1.475	32.41	6,217	0.752	46.75
December 12, 1894,	425.9	19.1	12,798	18.75	2,400	1.470	35.28	6,201	0.708	43.90
December 13, 1894,	430.9	23.1	12,938	18.60	2,407	1.580	38.03	6,112	0.761	46.51
December 14, 1894,	421.4	10.4	15,364	18.83	2,893	1.500	43.40	6,621	0.670	44.36*
December 15, 1894,	434.5	30.8	13,650	18.25	2,491	1.480	36.87	5,210	0.792	41.26
December 16, 1894,	417.8	3.2	12,364	20.97	2,593	1.610	41.75	6,345	0.645	44.15
December 17, 1894,	426.4	27.2	13,805	19.53	2,501	1.510	37.77	5,924	0.706	41.82
December 18, 1894,	433.2	25.9	13,993	19.28	2,698	1.465	38.99	5,621	0.857	48.17
December 19, 1894,	429.6	14.5	13,335	17.30	2,307	1.480	34.15	5,797	0.871	50.49
December 20, 1894,	434.1	22.2	13,475	17.77	2,396	1.450	34.73	5,133	0.835	42.90
December 21, 1894,	432.3	17.2	13,671	18.97	2,591	1.48	38.35	5,693	0.784	44.63
December 22, 1894,	418.7	20.4	13,790	19.56	2,697	1.46	39.36	6,390	0.747	47.73
December 23, 1894,	428.2	15.4	13,916	19.42	2,708	1.49	40.28	6,984	0.674	47.07
December 24, 1894,	431.8	21.8	13,167	19.70	2,594	1.45	37.62	6,104	0.675	41.20
December 25, 1894,	429.6	15.9	12,406	19.36	2,402	1.48	35.55	7,007	0.561	39.31
December 26, 1894,	435.5	26.3	13,398	18.04	2,417	1.45	35.06	7,550	0.555	41.90
December 27, 1894,	422.8	6.4	13,090	20.61	2,698	1.50	40.47	7,097	0.547	38.82
December 28, 1894,	430.9	25.0	12,623	19.84	2,505	1.48	37.08	6,236	0.618	38.54
December 29, 1894,	424.6	10.9	12,392	20.97	2,599	1.42	36.91	....	....	....
December 30, 1894,	430.5	19.1	10,867	21.11	2,294	1.49	34.18	5,712	0.694	39.64
December 31, 1894,	425.9	10.9	11,546	20.00	2,309	1.56	36.02	....	....	....
January 1, 1895,	435.8	24.5	11,399	21.93	2,500	1.48	37.00	4,477	0.985	44.10
January 2, 1895,	432.6	12.8	12,035	20.00	2,407	1.46	35.14	4,651	1.00	46.51
January 3, 1895,	439.6	26.0	14,049	19.29	2,710	1.49	40.38	....	....	....
January 4, 1895,	437.6	16.6	13,664	18.25	2,494	1.41	35.17	6,378	0.70	44.64
January 5, 1895,	438.2	21.0	14,769	19.59	2,893	1.45	41.95	6,379	0.71	45.29
January 6, 1895,	432.6	13.8	13,057	19.84	2,591	1.41	36.53	8,539	0.56	47.82
January 7, 1895,	435.2	21.2	12,609	19.05	2,402	1.48	35.55	....	....	....
January 8, 1895,	430.2	13.6	11,434	19.30	2,207	1.43	31.56	7,910	0.58	45.88
January 9, 1895,	436.0	24.6	13,077	19.84	2,595	1.41	36.59	6,495	0.66	42.87
January 10, 1895,	439.6	23.4	12,853*	20.15	2,590	1.62	41.96	6,987	0.63	44.02
January 11, 1895,	436.2	16.4	13,727	18.97	2,604	1.48	38.54	7,712	0.59	45.56
January 12, 1895,	430.6	13.6	13,098	18.32	2,400	1.52	36.48	6,539	0.66	43.16
January 13, 1895,	439.8	25.0	12,986	19.23	2,497	1.45	36.21	6,285	0.66	41.48
January 14, 1895,	434.8	16.6	14,825	17.57	2,605	1.43	37.25	....	....	....
January 15, 1895,	434.2	19.6	14,399	18.75	2,700	1.39	37.53	7,537	0.60	45.22
January 16, 1895,	428.2	13.0	12,497	20.00	2,500	1.31	32.75	8,483	0.53	44.96
January 17, 1895,	438.2	27.0	12,797	19.53	2,499	1.42	35.49	....	....	....
January 18, 1895,	426.4	6.8	12,084	19.17	2,317	1.38	31.98	7,889	0.58	45.76

Steer No. 3—Continued.

	Live weight. Kgs.	Water drunk. Kgs.	Feces.					Urine.		
			Weight. Grams.	Air-dry Weight.		Nitrogen.		Weight. Grams.	Nitrogen.	
				Per cent.	Weight. Grms.	Per cent. in air-dry matter.	Weight. Grams.		Per cent.	Weight. Grams.
January 19, 1895,	434.4	25.8	11,650	20.52	2,391	1.43	34.19	8,152	0.74	60.33
January 20, 1895,	436.8	21.8	13,203	16.67	2,201	1.41	31.03	7,567	0.63	47.67
January 21, 1895,	435.6	17.2	11,133	18.02	2,006	1.43	28.69	8,579	0.52	44.61
January 22, 1895,	438.0	20.6	13,266	18.04	2,393	1.43	34.22	6,175	0.70	43.22
January 23, 1895,	427.4	5.8	10,683	20.57	2,198	1.49	32.75	6,345	0.75	47.59
January 24, 1895,	436.2	24.0	11,890	19.33	2,298	1.42	32.63	....	....	....
January 25, 1895,	432.8	11.6	11,828	20.34	2,406	1.55	37.29	....	....	....
January 26, 1895,	438.0	22.5	12,905	19.38	2,501	1.45	36.27	....	....	....
January 27, 1895,	434.6	17.2	....	....	....	....	....	....	....	....
January 28, 1895,	436.6	24.2	....	....	....	....	....	....	....	....
January 29, 1895,	423.6	6.6	12,302	20.33	2,501	1.39	34.77	....	....	....
January 30, 1895,	428.0	18.8	....	....	....	....	....	....	....	....
January 31, 1895,	438.8	26.2	....	....	....	....	....	....	....	....
February 1, 1895,	437.0	15.2	13,770	18.15	2,499	1.49	37.24	8,205	0.56	45.95
February 2, 1895,	436.4	....	14,983	18.67	2,798	1.49	41.69	7,172	0.59	42.32
February 3, 1895,	433.0	16.4	12,250	19.00	2,328	1.48	34.46	8,717	0.53	46.20
February 4, 1895,	440.8	25.2	12,973	19.00	2,465	1.25	30.82	6,805	0.60	40.83
February 5, 1895,	433.0	14.2	15,272	21.50	3,284	1.32	43.35	8,847	0.56	49.54
February 6, 1895,	417.2	3.2	11,373	19.50	2,218	1.41	31.27	8,565	0.60	51.39
February 7, 1895,	433.0	31.8	10,580	21.00	2,222	1.36	30.22	5,717	0.70	40.02
February 8, 1895,	438.3	24.0	14,133	18.00	2,544	1.57	39.94	5,205	0.845	43.98
February 9, 1895,	447.6	24.9	13,850	18.50	2,562	1.53	39.20	5,467	0.91	49.75
February 10, 1895,	432.6	6.4	13,543	18.00	2,438	1.43	34.86	8,095	0.56	45.33
February 11, 1895,	449.4	39.2	14,390	15.50	2,230	1.38	30.78	7,007	0.64	44.85
February 12, 1895,	437.4	10.3	13,883	18.00	2,499	1.46	36.49	6,645	0.71	47.18
February 13, 1895,	441.8	24.0	....	....	....	....	....	6,087	0.84	51.13
February 14, 1895,	434.8	....	13,523	16.00	2,164	1.56	33.76	6,605	0.74	48.88
February 15, 1895,	433.6	19.2	16,535	17.25	2,853	1.45	41.37	6,325	0.68	43.02
February 16, 1895,	431.4	19.0	....	....	....	....	....	....	....	....
February 17, 1895,	429.2	18.8	....	....	....	....	....	....	....	....
February 18, 1895,	432.3	23.8	....	....	....	....	....	....	....	....
February 19, 1895,	419.0	3.1	....	....	....	....	....	....	....	....
February 20, 1895,	431.6	32.0	....	....	....	....	....	....	....	....
February 21, 1895,	431.0	16.8	....	....	....	....	....	....	....	....
February 22, 1895,	440.6	27.6	....	....	....	....	....	....	....	....
February 23, 1895,	431.2	6.4	....	....	....	....	....	....	....	....
February 24, 1895,	444.8	31.6	....	....	....	....	....	....	....	....
February 25, 1895,	427.6	1.0	....	....	....	....	....	....	....	....
February 26, 1895,	427.9	15.8	....	....	....	....	....	....	....	....

February 27, 1895,	437.8	26.1	......	......	......	......	......	......	......	......
February 28, 1895,	436.0	15.0	......	......	......	......	......	......	......	......
March 1, 1895,	437.2	18.6	......	......	......	......	......	......	......	......
March 2, 1895,	443.0	24.6	......	......	......	......	......	......	......	......
March 3, 1895,	428.4	4.8	......	......	......	......	......	......	......	......
March 4, 1895,	433.4	21.0	......	......	......	......	......	......	......	......
March 5, 1895,	436.8	20.6	......	......	......	......	......	......	......	......
March 6, 1895,	418.6	1.0	12,853	18.50	2,378	1.55	36.86	7,365	0.61	44.93
March 7, 1895,	427.0	26.2	11,520	18.25	2,102	1.55	32.58	6,125	0.65	39.81
March 8, 1895,	443.0	35.0	13,948	17.50	2,441	1.42	34.66	5,877	0.75	44.08
March 9, 1895,	421.4	1.0	12,940	18.50	2,394	1.46	34.95	8,505	0.49	41.67
March 10, 1895,	430.4	26.0	12,743	18.25	2,326	1.48	34.43	5,555	0.65	36.11
March 11, 1895,	441.9	28.4	12,638	18.00	2,275	1.53	34.81	4,945	0.915	45.25
March 12, 1895,	428.0	3.5	11,983	19.50	2,337	1.60	37.40	6,067	0.84	50.88
March 13, 1895,	438.8	29.0	13,440	19.00	2,554	1.60	40.87	5,035	0.93	46.83
March 14, 1895,	429.0	6.4	11,063	20.00	2,213	1.46	32.31	6,107	0.75	45.80
March 15, 1895,	442.4	29.4	12,180	19.67	2,396	1.42	34.02	4,965	0.70	34.76
March 16, 1895,	432.3	6.8	12,958	18.33	2,375	1.48	35.15	5,565	0.58	32.28
March 17, 1895,	436.2	20.7	12,150	17.33	2,106	1.53	32.22	5,995	0.54	32.37
March 18, 1895,	434.8	13.6	10,562	18.00	1,901	1.59	30.23	6,097	0.51	31.09
March 19, 1895,	438.4	18.6	11,512	17.00	1,957	1.56	30.53	5,755	0.55	31.65
March 20, 1893,	436.6	14.2	11,253	16.67	1,876	1.66	31.14	5,827	0.58	33.80
March 21, 1895,	431.0	11.4	10,940	18.00	1,969	1.50	29.54	5,885	0.57	33.55
March 22, 1895,	435.5	18.6	10,272	17.33	1,780	1.53	27.24	4,777	0.69	32.96
March 23, 1895,	432.4	11.5	9,840	18.33	1,804	1.56	28.14	5,055	0.72	36.40
March 24, 1895,	431.2	16.4	11,953	17.00	2,032	1.48	30.07	5,916	0.66	39.05
March 25, 1895,	427.4	13.4	11,060	16.33	1,806	1.45	26.19	5,475	0.63	34.49
March 26, 1895,	437.0	26.4	12,403	16.33	2,026	1.46	29.58	4,087	0.75	30.65
March 27, 1895,	421.0	1.0	11,220	20.00	2,244	1.45	32.54	5,945	0.60	35.67
March 28, 1895,	425.6	21.8	12,455	16.67	2,076	1.48	30.73	5,309	0.61	32.39
March 29, 1895,	431.6	24.4	14,270	16.00	2,283	1.39	31.73	4,555	0.75	34.16
March 30, 1895,	434.1	16.4	11,743	17.33	2,035	1.38	28.08	4,047	0.73	29.54
March 31, 1895,	435.4	15.9	12,600	17.00	2,176	1.32	28.72	3,875	0.70	27.12
April 1, 1895,	434.2	16.8	13,353	17.33	2.314	1.36	31.47	4,267	0.62	26.45
April 2, 1895,	421.0	1.0	10,230	18.50	1,893	1.39	26.31	5,345	0.40	21.38
April 3, 1895,	425.4	18.0	10,593	18.67	1,978	1.34	26.51	4,867	0.46	22.39
April 4, 1895,	433.4	24.6	13,850	17.33	2,400	1.31	31.44	4,535	0.50	22.68
April 5, 1895,	435.7	20.4	13,615	17.17	2,338	1 27	29.69	5,117	0.46	23.54
April 6, 1895,	430.8	13.7	13,210	17.33	2,290	1.34	30.69	5,585	0.43	24.02
April 7, 1895,	434.6	20.2	12,113	17.00	2,059	1.31	26.97	4,542	0.53	24.07
April 8, 1895,	429.6	14.2	13,859	17.33	2,402	1.34	32.19	5,695	0.50	28.48
April 9, 1895,	431.0	19.0	12,203	17.50	2,136	1.39	29.69	5,797	0.45	26.09
April 10, 1895,	430.0	18.0	12,355	17.67	2,184	1.32	28.83	5,955	0.48	25.61
April 11, 1895,	411.6	0.0	10,923	20.00	2,185	1.25	27.31	......	......	......
April 12, 1893,	422.4	25.0	10,290	19.33	1,989	1.32	26.26	......	......	......
April 13, 1895,	433.0	23.0	10,453	18.26	1,909	1.39	26.54	3,907	0.62	24.22
April 14, 1895,	425.2	10.4	13,398	16.42	2,200	1.42	31.24	4,885	0.55	26.87
April 15, 1895,	433.4	24.7	12,793	16.01	2,048	1.29	26.42	4,235	0.48	20.33
April 16, 1895,	421.4	9.0	13,780	17.76	2,447	1.28	31.32	8,665	0.31	26.86
April 17, 1895,	430.2	27.4	13,243	17.05	2,258	1.21	27.32	5,622	0.36	20.24
April 18, 1895,	428.6	14.8	11,550	16.94	1,957	1.31	25.64	5,793	0.37	21.43
April 19, 1895,	430.0	19.8	13,533	17.77	2,405	1.28	30.79	5,459	0.36	19.65
April 20, 1895,	434.8	22.4	13,120	17.17	2,253	1.29	29.07	5,335	0.41	21.87
April 21, 1895,	431.1	13.8	12,542	18.00	2,258	1.28	28.90	4,207	0.47	19.77
April 22, 1895,	435.2	21.3	12,510	16.67	2,086	1.34	27.95	4,845	0.44	21.32
April 23, 1895,	428.6	11.2	13,163	17.67	2,326	1.29	30.01	5,249	0.50	26.25
April 24, 1895,	......	18.0	......	......						

Experiments of 1894-5.

TEN-DAY AVERAGES.

Steer No. 1.

	Live weight. Kgs.	Water drunk. Kgs.	Feces.			Urine.		Air-dry matter digested. Grams.
			Fresh weight. Grams.	Air-dry weight. Grams.	Nitrogen. Grams.	Weight. Grams.	Nitrogen. Grams.	
1894-5.								
Nov. 26-Dec. 5, ...	439.3	16.8	....	....	....	....	....	....
Nov. 27-Dec. 6, ...	440.2	17.5	....	....	....	....	....	....
Nov. 28-Dec. 7, ...	439.6	16.3	13,242	2,759	45.71	....	....	3,151
Nov. 29-Dec. 8, ...	440.0	17.5	13,319	2,748	43.73	5,601	53.77	3,162
Nov. 30-Dec. 9, ...	440.0	18.2	13,584	2,759	43.30	5,684	54.11	3,172
Dec. 1-10, ...	440.5	17.9	13,549	2,704	42.02	5,585	53.53	3,228
Dec. 2-11, ...	441.6	18.6	13,653	2,698	41.25	5,406	51.95	3,286
Dec. 3-12, ...	440.9	17.3	13,660	2,683	40.59	5,652	51.30	3,344
Dec. 4-13, ...	443.6	19.7	13,458	2,627	39.81	5,717	50.09	3,355
Dec. 5-14, ...	444.3	18.4	13,296	2,569	38.99	5,791	48.97	3,374
Dec. 6-15, ...	445.0	17.9	13,174	2,511	38.13	5,874	48.30	3,355
Dec. 7-16, ...	445.2	17.9	13,234	2,491	37.77	5,975	47.60	3,395
Dec. 8-17, ...	446.1	18.9	13,269	2,462	37.12	6,059	46.76	3,380
Dec. 9-18, ...	446.6	18.2	13,393	2,472	37.32	5,986	45.60	3,390
Dec. 10-19, ...	447.3	18.4	13,142	2,422	36.54	6,058	45.32	3,440
Dec. 11-20, ...	447.9	17.9	13,089	2,428	36.30	6,085	44.25	3,415
Dec. 12-21, ...	448.4	18.2	13,009	2,408	35.94	6,192	43.77	3,395
Dec. 13-22, ...	449.8	18.4	12,670	2,349	35.09	5,985	43.87	3,422
Dec. 14-23, ...	449.3	17.7	12,774	2,379	35.52	6,059	44.15	3,446
Dec. 15-24, ...	449.3	17.9	12,878	2,404	35.80	6,009	43.83	3,443
Dec. 16-25, ...	450.0	18.4	12,803	2,382	35.47	6,040	43.61	3,456
Dec. 17-26, ...	449.6	17.7	12,802	2,372	35.39	6,301	43.73	3,442
Dec. 18-27, ...	449.8	18.6	12,821	2,390	35.70	6,465	43.31	3,475
Dec. 19-28, ...	449.3	18.4	12,663	2,391	35.61	6,734	43.09	3,520
Dec. 20-29, ...	449.1	18.4	12,771	2,420	36.27	6,720	41.88	3,508
Dec. 21-30, ...	449.1	18.4	12,697	2,411	36.15	6,690	41.07	3,504
Dec. 22-31, ...	448.9	17.7	12,552	2,390	36.38	6,690	41.21	3,543
Dec. 23-Jan. 1, ...	448.5	18.2	12,683	2,431	37.23	6,971	40.99	3,532
Dec. 24-Jan. 2, ...	449.2	19.0	12,767	2,439	36.32	6,892	40.06	3,580
Dec. 25-Jan. 3, ...	449.5	18.6	12,620	2,410	35.69	6,890	40.47	3,556
Dec. 26-Jan. 4, ...	449.5	18.3	12,716	2,431	35.92	6,846	41.08	3,554
Dec. 27-Jan. 5, ...	450.5	18.4	12,450	2,392	35.29	6,476	40.66	3,564
Dec. 28-Jan. 6, ...	450.6	17.6	12,508	2,414	35.70	6,301	41.13	3,543
Dec. 29-Jan. 7, ...	451.4	18.3	12,669	2,414	35.77	6,012	41.47	3,482
Dec. 30-Jan. 8, ...	450.9	17.3	12,757	2,403	35.61	6,106	42.90	3,469
Dec. 31-Jan. 9, ...	451.3	18.6	13,049	2,412	35.51	6,199	43.59	3,457
Jan. 1-10, ...	451.5	19.0	13,592	2,462	36.25	6,252	43.42	3,416
Jan. 2-11, ...	451.7	18.9	13,734	2,463	36.44	6,171	43.22	3,406
Jan. 3-12, ...	451.5	19.0	13,810	2,464	36.59	6,824	43.26	3,355
Jan. 4-13, ...	450.8	18.7	13,993	2,493	37.01	6,428	43.06	3,406
Jan. 5-14, ...	450.4	18.9	14,028	2,492	37.13	6,454	42.34	3,396
Jan. 6-15, ...	449.8	19.2	14,316	2,531	37.87	6,556	42.39	3,386
Jan. 7-16, ...	449.6	19.3	14,161	2,480	37.11	6,509	41.82	3,404
Jan. 8-17, ...	449.5	19.5	14,256	2,490	37.43	6,569	41.87	3,382
Jan. 9-18, ...	449.9	19.8	14,410	2,500	37.59	6,592	41.66	3,360
Jan. 10-19, ...	450.0	19.3	14,209	2,482	37.44	6,692	41.99	3,38[illegible]
Jan. 11-20, ...	450.2	19.4	13,945	2,461	37.01	6,724	41.85	3,314
Jan. 12-21, ...	450.3	19.5	13,862	2,440	36.58	6,663	41.68	3,300
Jan. 13-22, ...	450.5	19.3	13,828	2,420	36.31	6,623	41.53	3,285
Jan. 14-23, ...	450.0	19.9	13,761	2,400	36.18	6,595	41.48	3,252
Jan. 15-24, ...	450.6	18.8	13,674	2,371	35.79	6,564	41.45	3,245
Jan. 16-25, ...	450.2	18.8	13,647	2,342	35.35	6,548	41.52	3,223
Jan. 17-26, ...	449.7	18.2	13,730	2,332	35.25	6,639	42.14	3,181
Jan. 18-27, ...	448.9	17.9	13,650	2,322	35.10	6,621	41.81	3,236
Jan. 19-28, ...	449.0	18.5	13,576	2,321	35.24	6,495	40.98	3,211
Jan. 20-29, ...	448.5	17.9	13,658	2,350	35.79	6,366	40.66	3,254
Jan. 21-30, ...	448.4	18.1	13,460	2,321	35.56	6,221	40.40	3,290
Jan. 22-31, ...	448.1	17.7	13,604	2,371	36.47	6,106	41.03	3,260
Jan. 23-Feb. 1, ...	447.6	17.1	13,441	2,353	36.32	6,019	41.24	3,247
Jan. 24-Feb. 2, ...	448.2	18.2	13,352	2,343	36.10	5,980	41.16	3,270
Jan. 25-Feb. 3, ...	448.7	18.3	13,576	2,413	37.12	6,004	41.33	3,248
Jan. 26-Feb. 4, ...	448.8	17.0	13,655	2,467	37.95	5,961	41.07	3,275
Jan. 27-Feb. 5, ...	449.1	17.6	13,569	2,485	38.18	6,023	41.43	3,299
Jan. 28-Feb. 6, ...	450.0	17.4	13,415	2,522	38.31	6,075	42.20	3,319
Jan. 29-Feb. 7, ...	451.0	17.9	13,255	2,510	38.09	6,053	42.36	3,323
Jan. 30-Feb. 8, ...	451.2	17.2	13,224	2,501	37.95	6,022	42.58	3,347
Jan. 31-Feb. 9, ...	451.4	17.0	13,188	2,496	38.15	6,145	43.24	3,349
Feb. 1-10, ...	452.4	17.7	13,238	2,504	38.08	6,097	43.33	3,381
Feb. 2-11, ...	453.1	17.6	13,175	2,492	37.65	6,182	44.10	3,332
Feb. 3-12, ...	453.8	18.0	13,268	2,502	37.78	6,207	44.46	3,332
Feb. 4-13, ...	454.4	18.0	13,157	2,467	37.11	6,223	44.70	3,372
Feb. 5-14, ...	455.8	20.2	13,242	2,518	37.64	6,356	45.06	3,316

Steer No. 1—Continued.

	Live weight. Kgs.	Water drunk. Kgs.	Feces.			Urine.		Air-dry matter digested. Grams.
			Fresh weight. Grams.	Air-dry weight. Grams.	Nitrogen. Grams.	Weight. Grams.	Nitrogen. Grams.	
1894-5.								
Feb. 6-15, ...	455.8	18.1	13,241	2,510	37.49	6,434	45.09	3,308
Feb. 7-16, ...	455.8	19.2	....	....	....	....	....	....
Feb. 8-17, ...	453.5	16.7	....	....	....	....	....	....
Feb. 9-18, ...	453.3	19.7	....	....	....	....	....	....
Feb. 10-19, ...	453.0	20.0	....	....	....	....	....	....
Feb. 11-20, ...	452.1	19.7	....	....	....	....	....	....
Feb. 12-21, ...	451.4	19.7	....	....	....	....	....	....
Feb. 13-22, ...	450.4	19.0	....	....	....	....	....	....
Feb. 14-23, ...	449.5	18.7	....	....	....	....	....	....
Feb. 15-24, ...	448.1	18.0	....	....	....	....	....	....
Feb. 16-25, ...	448.1	19.5	....	....	....	....	....	....
Feb. 17-26, ...	445.9	17.2	....	....	....	....	....	....
Feb. 18-27, ...	446.2	19.3	....	....	....	....	....	....
Feb. 19-28, ...	447.3	18.9	....	....	....	....	....	....
Feb. 20-March 1, ...	447.5	17.9	....	....	....	....	....	....
Feb. 21-March 2, ...	447.8	17.7	....	....	....	....	....	....
Feb. 22-March 3, ...	448.4	17.9	....	....	....	....	....	....
Feb. 23-March 4, ...	447.2	16.2	....	....	....	....	....	....
Feb. 24-March 5, ...	446.8	17.9	....	....	....	....	....	....
Feb. 25-March 6, ...	446.9	18.4	....	....	....	....	....	....
Feb. 26-March 7, ...	447.6	18.9	....	....	....	....	....	....
Feb. 27-March 8, ...	449.9	20.4	....	....	....	....	....	....
Feb. 28-March 9, ...	451.3	19.5	....	....	....	....	....	....
March 1-10, ...	451.1	17.9	....	....	....	....	....	....
March 2-11, ...	451.8	18.6	....	....	....	....	....	....
March 3-12, ...	452.0	18.3	....	....	....	....	....	....
March 4-13, ...	452.2	18.5	....	....	....	....	....	....
March 5-14, ...	453.7	19.9	....	....	....	....	....	....
March 6-15, ...	454.5	18.4	12,573	2,444	36.09	5,768	41.81	3,234
March 7-16, ...	455.1	18.2	12,718	2,442	36.41	5,854	41.40	3,293
March 8-17, ...	454.6	17.1	12,552	2,366	35.57	6,025	40.01	3,376
March 9-18, ...	454.3	17.0	12,466	2,329	34.90	6,140	38.64	3,421
March 10-19, ...	454.1	17.1	12,406	2,292	34.39	6,303	37.58	3,477
March 11-20, ...	453.5	16.7	12,258	2,242	33.69	6,366	36.59	3,529
March 12-21, ...	452.4	16.2	12,268	2,231	33.36	6,507	35.68	3,546
March 13-22, ...	451.7	16.3	12,156	2,208	32.93	6,514	34.85	3,562
March 14-23, ...	450.8	16.1	12,028	2,189	32.64	6,746	34.53	3,635
March 15-24, ...	450.6	17.0	11,946	2,155	32.35	6,802	33.72	3,585
March 16-25, ...	450.0	16.5	11,800	2,122	31.96	6,857	33.19	3,547
March 17-26, ...	449.1	15.7	11,323	2,032	30.76	6,831	32.68	3,478
March 18-27, ...	449.2	16.5	11,072	2,032	30.80	6,724	32.77	3,416
March 19-28, ...	449.3	16.1	10,918	2,020	30.85	6,550	32.62	3,411
March 20-29, ...	449.2	16.0	10,933	2,039	31.13	6,324	31.92	3,420
March 21-30, ...	449.1	15.5	10,931	2,051	30.95	6,337	30.77	3,419
March 22-31, ...	450.0	16.3	10,688	2,037	30.45	6,218	29.96	3,479
March 23-April 1, ..	450.3	15.8	10,465	2,0[illegible]9	29.95	6,171	29.37	3,495
March 24-April 2, ..	450.7	15.5	10,347	1,991	29.44	5,910	28.10	3,484
March 25-April 3, ..	450.7	14.6	10,080	1,962	28.68	5,797	27.53	3,506
March 26-April 4, ..	451.3	15.1	10,097	1,977	28.45	5,854	26.93	3,523
March 27-April 5, ..	451.7	15.6	10,234	2,018	28.47	6,072	26.37	3,586
March 28-April 6, ..	452.1	15.7	10,379	2,028	28.19	6,313	25.52	3,630
March 29-April 7, ..	451.9	15.7	10,497	2,052	28.21	6,414	24.77	3,642
March 30-April 8, ..	452.4	16.2	10,379	2,030	27.67	6,454	24.35	3,626
March 31-April 9, ..	452.8	16.6	10,354	2,027	27.71	6,501	24.91	3,656
April 1-10, ...	452.4	16.1	10,874	2,025	27.70	6,767	25.41	3,649
April 2-11, ...	452.6	16.9	10,574	2,052	27.79	6,719	25.21	3,664
April 3-12, ...	453.1	16.8	10,446	2,032	27.37	6.701	25.35	3,714
April 4-13, ...	453.1	16.6	10,613	2,049	27.75	6,691	25.52	3,683
April 5-14, ...	453.5	16.9	10,568	2,038	27.88	6,542	25.61	3,652
April 6-15, ...	453.9	16.3	10,365	1,991	27.53	6,520	25.91	3,677
April 7-16, ...	453.6	15.8	10,575	2,026	28.15	6,422	26.00	3,652
April 8-17, ...	453.1	15.6	10,767	2,050	28.16	6,438	26.12	3,616
April 9-18, ...	452.8	15.6	10,710	2,019	27.62	6,402	25.88	3,610
April 10-19, ...	452.6	15.5	10,738	2,030	27.44	6,185	25.08	3,572
April 11-20, ...	452.5	15.4	10,832	2,052	27.58	5,718	23.91	3,467
April 12-21, ...	452.5	15.3	10,661	2,044	27.50	5,686	23.83	3,574
April 13-22, ...	452.3	16.4	10,734	2,068	27.55	5,604	23.22	3,543
April 14-23, ...	452.3	16.6	10,656	2,159	27.15	5,583	22.75	3,445

Steer No. 2.

Nov. 26-Dec. 5, ...	488.8	17.2	....	....	....	....	....	....
Nov. 27-Dec. 6, ...	488.8	16.1	....	....	....	....	....	....
Nov. 28-Dec. 7, ...	489.5	16.6	11,462	2,553	43.58	6,034	49.40	3,381
Nov. 29-Dec. 8, ...	489.0	16.1	11,510	2,553	43.55	6,115	50.16	3,392
Nov. 30-Dec. 9, ...	490.0	17.5	11,464	2,523	42.46	6,277	51.69	3,333

Steer No. 2—Continued.

	Live weight. Kgs.	Water drunk. Kgs.	Feces.			Urine.		Air-dry matter digested. Grams.
			Fresh weight. Grams.	Air-dry weight. Grams.	Nitrogen. Grams.	Weight. Grams.	Nitrogen. Grams.	
1894-5.								
Dec. 1-10,	490.0	16.8	11,437	2,474	41.15	6,395	52.67	3,403
Dec. 2-11,	490.2	17.0	11,483	2,463	40.22	6,442	53.02	3,434
Dec. 3-12,	490.2	16.6	11,858	2,522	40.67	6,443	52.60	3,345
Dec. 4-13,	490.2	17.3	11,577	2,452	39.53	6,520	51.92	3,416
Dec. 5-14,	491.3	18.6	11,471	2,421	39.12	6,468	50.49	3,368
Dec. 6-15,	491.1	17.7	11,927	2,510	40.63	6,426	49.69	3,339
Dec. 7-16,	491.1	18.1	11,766	2,430	39.15	6,397	49.50	3,350
Dec. 8-17,	491.1	18.4	12,048	2,468	38.50	6,548	49.32	3,331
Dec. 9-18,	491.3	18.4	12,219	2,488	38.42	6,499	47.35	3,344
Dec. 10-19,	491.1	18.4	12,192	2,467	38.32	6,439	45.60	3,403
Dec. 11-20,	490.8	18.1	12,321	2,477	38.[illegible]2	6,354	43.86	3,299
Dec. 12-21,	490.9	18.4	12,325	2,454	38.27	6,352	42.28	3,373
Dec. 13-22,	490.2	19.1	12,050	2,386	37.25	6,402	41.49	3,417
Dec. 14-23,	489.7	18.6	12,710	2,495	38.76	6,390	40.76	3,410
Dec. 15-24,	489.9	19.1	12,460	2,426	37.55	6,415	40.74	3,465
Dec. 16-25,	490.4	19.3	12,335	2,387	36.99	6,504	41.01	3,498
Dec. 17-26,	490.6	18.9	12,461	2,408	37.47	6,651	41.33	3,492
Dec. 18-27,	491.1	18.8	12,346	2,368	36.78	6,549	40.35	3,495
Dec. 19-28,	491.3	19.3	12,238	2,349	36.54	6,684	40.34	3,477
Dec. 20-29,	491.7	19.3	12,353	2,370	36.75	6,686	39.84	3,512
Dec. 21-30,	491.7	19.1	12,421	2,891	36.98	6,605	39.23	3,541
Dec. 22-31,	492.0	19.1	12,436	2,433	37.50	6,604	38.91	3,539
Dec. 23-Jan. 1,	493.9	19.3	12,351	2,422	37.17	6,650	38.99	3,540
Dec. 24-Jan. 2,	493.8	18.5	12,033	2,402	36.75	6,633	38.53	3,579
Dec. 25-Jan. 3,	493.9	18.5	12,0[illegible]0	2,414	36.95	6,686	38.67	3.577
Dec. 26-Jan. 4,	493.8	18.4	11,975	2,423	36.94	6,647	38.46	3,556
Dec. 27-Jan. 5,	494.4	18.6	11,796	2,393	36.55	6,494	37.93	3,595
Dec. 28-Jan. 6,	494.4	18.1	11,726	2,393	36.67	6,541	39.09	3,675
Dec. 29-Jan. 7,	494.7	18.3	11,863	2,412	36.79	6,399	39.80	3,702
Dec. 30-Jan. 8,	493.2	16.3	11,733	2,372	36.33	6,441	39.97	3,609
Dec. 31-Jan. 9,	493.6	17.8	11,252	2,280	35.02	6,404	39.98	3,660
Jan. 1-10,	494.5	18.2	11,218	2,242	34.27	6,306	40.52	3,569
Jan. 2-11,	494.8	17.9	11,563	2,323	35.68	6,247	41.59	3,598
Jan. 3-12,	495.8	18.6	11,497	2,261	34.70	6,236	42.76	3,537
Jan. 4-13,	495.9	17.9	11,958	2,340	35.62	6,164	43.12	3,526
Jan. 5-14,	496.2	17.9	11,777	2,300	35.04	6,152	43.04	3,515
Jan. 6-15,	496.3	18.0	12,026	2,319	35.60	6,219	43.50	3,495
Jan. 7-16,	496.7	18.4	12,046	2,360	35.69	6,245	43.00	3,424
Jan. 8-17,	495.2	16.4	12,124	2,371	35.76	6,292	43.15	3,395
Jan. 9-18,	496.4	19.2	12,233	2,391	35.94	6,175	42.45	3,462
Jan. 10-19,	497.2	19.1	12,616	2,462	36.85	6,122	41.91	3,410
Jan. 11-20,	496.7	17.7	12,490	2,448	36.75	6,219	43.00	3,386
Jan. 12-21,	496.7	17.6	11,985	2,3[illegible]8	34.79	6,099	41.46	3,303
Jan. 13-22,	497.0	17.7	11,925	2,347	35.01	6,102	41.09	3,270
Jan. 14-23,	497.2	17.7	11,768	2,328	34.93	6,149	41.19	3,237
Jan. 15-24,	496.9	17.2	11,811	2,3[illegible]8	35.41	6,270	41.75	3,212
Jan. 16-25,	497.0	17.4	11,654	2,357	35.32	6,191	40.58	3,203
Jan. 17-26,	497.2	17.5	11,652	2,347	35.18	6,170	40.05	3,176
Jan. 18-27,	498.9	19.0	11,685	2,355	35.31	6,174	39.70	3,168
Jan. 19-28,	499.4	17.6	11,554	2,346	35.01	6,228	40.32	3,133
Jan. 20-29,	498.5	16.3	11,522	2,355	35.08	6,381	41.47	3,118
Jan. 21-30,	499.1	17.5	11,369	2,389	35.87	6,289	40.01	3,194
Jan. 22-31,	499.0	17.3	11,570	2,449	37.07	6,406	40.67	3,202
Jan. 23-Feb. 1,	498.3	16.5	11,6[illegible]3	2,489	37.79	6,442	40.44	3,268
Jan. 24-Feb. 2,	498.8	17.3	11,312	2,439	36.95	6,370	40.10	3,326
Jan. 25-Feb. 3,	499.5	17.5	11,514	2,471	37.51	6,192	39.51	3,416
Jan. 26-Feb. 4,	499.4	16.8	11,377	2,446	37.15	6,329	41.36	3,416
Jan. 27-Feb. 5,	499.4	16.8	11,278	2,429	36.81	6,226	41.42	3,449
Jan. 28-Feb. 6,	498.9	16.1	11,128	2,354	35.84	6,241	41.06	3,478
Jan. 29-Feb 7,	499.4	17.2	11,157	2,369	36.26	6,135	40.97	3,540
Jan. 30-Feb. 8,	500.1	17.2	11,101	2,251	36.08	5,984	40.65	3,420
Jan. 31-Feb. 9,	499.9	16.3	11,382	2,337	35.85	6,095	41.84	3,559
Feb. 1-10,	499.7	17.1	11,290	2,287	34.83	6,084	42.06	3,648
Feb. 2-11,	499.3	16.9	11,423	2,319	34.96	5,992	42.08	3,609
Feb. 3-12,	499.9	18.0	11,385	2,292	34.54	6,092	42.95	3,532
Feb. 4-13,	499.3	16.8	11,190	2,200	33.09	6,123	43.98	3,639
Feb. 5-14,	500.0	18.3	11,481	2,236	33.70	6,049	44.02	3,593
Feb. 6-15,	499.1	17.1	11,860	2,310	34.71	6,099	45.16	3,508
Feb. 7-16,	499.8	18.7	....	....	....	....	....	....
Feb. 8-17,	497.9	16.2	....	....	....	....	....	....
Feb. 9-18,	497.7	18.0	....	....	....	....	....	....
Feb. 10-19,	497.0	17.6	....	....	....	....	....	....
Feb. 11-20,	496.9	17.8	....	....	....	....	....	....
Feb. 12-21,	496.1	16.8	....	....	....	....	....	....
Feb. 13-22,	495.5	16.7	....	....	....	....	....	....
Feb. 14-23,	494.9	16.7	....	....	....	....	....	....
Feb. 15-24,	494.3	16.3	....	....	....	....	....	....
Feb. 16-25,	494.2	16.8	....	....	....	....	....	....

Steer No. 2—Continued.

	Live weight. Kgs.	Water drunk. Kgs.	Feces.			Urine.		Air-dry matter digested. Grams.
			Fresh weight. Grams.	Air-dry weight. Grams.	Nitrogen. Grams.	Weight. Grams.	Nitrogen. Grams.	
1894-5.								
Feb. 17-26, ...	493.2	15.8	....	....	....	....	....	....
Feb. 18-27, ...	494.3	17.9	....	....	....	....	....	....
Feb. 19-28, ...	494.1	16.5	....	....	....	....	....	....
Feb. 20-March 1, ..	492.8	15.3	....	....	....	....	....	....
Feb. 21-March 2, ..	492.0	15.6	....	....	....	....	....	....
Feb. 22-March 3, ..	494.0	18.1	....	....	....	....	....	....
Feb. 23-March 4, ..	492.1	14.6	....	....	....	....	....	....
Feb. 24-March 5, ..	492.5	17.0	....	....	....	....	....	....
Feb. 25-March 6, ..	491.9	15.9	....	....	....	....	....	....
Feb. 26-March 7, ..	492.5	16.9	....	....	....	....	....	....
Feb. 27-March 8, ..	493.3	17.0	....	....	....	....	....	....
Feb. 28-March 9, ..	493.6	16.5	....	....	....	....	....	....
March 1-10, ...	493.5	16.3	....	....	....	....	....	....
March 2-11, ...	495.6	18.4	....	....	....	....	....	....
March 3-12, ...	496.3	17.3	....	....	....	....	....	....
March 4-13, ...	495.8	16.1	....	....	....	....	....	....
March 5-14, ...	495.5	16.1	....	....	....	....	....	....
March 6-15, ...	495.8	16.2	11,039	2,247	34.54	5,559	42.61	3,251
March 7-16, ...	496.9	17.0	11,155	2,245	34.67	5,656	41.89	3,363
March 8-17, ...	497.2	16.9	11,631	2,306	35.58	5,803	40.67	3,464
March 9-18, ...	496.9	16.4	11,723	2,312	35.80	5,961	39.56	3,504
March 10-19, ...	495.2	14.8	11,477	2,222	34.37	6,129	38.67	3,539
March 11-20, ...	495.7	16.5	11,188	2,154	33.58	6,011	36.44	3,581
March 12-21, ...	495.8	16.1	11,338	2,148	33.47	6,054	35.59	3,602
March 13-22, ...	495.7	16.4	11,523	2,146	33.40	6,247	35.08	3,591
March 14-23, ...	495.5	16.6	11,510	2,137	33.24	6,516	34.46	3,620
March 15-24, ...	496.8	18.3	11,435	2,099	32.71	6,676	33.44	3,687
March 16-25, ...	497.0	17.5	11,595	2,093	32.63	6,755	32.62	3,635
March 17-26, ...	495.7	16.4	11,380	2,047	31.81	6,857	31.86	3,572
March 18-27, ...	494.8	16.2	10,515	1,930	30.04	6,983	31.13	3,465
March 19-28, ...	494.7	16.9	10,406	1,932	30.00	6,923	30.14	3,488
March 20-29, ...	495.9	18.2	10,380	1,945	30.17	6,859	29.85	3,507
March 21-30, ...	495.1	16.5	10,591	2,002	30.76	6,866	29.70	3,456
March 22-31, ...	494.8	17.1	10,215	1,960	29.86	6,914	29.32	3,446
March 23, April 1, ..	494.8	16.8	9,874	1,922	28.95	6,667	27.22	3,484
March 24-April 2, ..	494.9	16.9	9,964	1,954	29.41	6,493	26.38	3,504
March 25-April 3, ..	495.1	16.5	10,061	1,995	29.84	6,166	25.22	3,452
March 26-April 4, ..	494.7	15.8	9,870	1,978	29.34	6,128	25.53	3,491
March 27-April 5, ..	495.7	16.5	9,838	1,998	29.33	5,949	24.80	3,536
March 28-April 6, ..	495.9	16.1	10,343	2,081	30.21	5,781	24.18	3,608
March 29-April 7, ..	496.1	16.3	10,389	2,084	30.01	5,933	24.32	3,628
March 30-April 8, ..	496.2	16.3	10,321	2,080	29.67	6,042	24.08	3,500
March 31-April 9, ..	496.7	16.8	10,201	2,049	29.08	5,964	23.73	3,561
April 1-10, ...	496.4	15.3	10,659	2,039	30.27	5,765	23.32	3,590
April 2-11, ...	496.2	15.4	10,730	2,178	30.93	5,816	23.98	3,546
April 3-12, ...	496.4	15.4	10,458	2,127	29.86	5,685	24.01	3,583
April 4-13, ...	496.2	15.1	10,376	2,108	29.52	5,855	25.23	3,614
April 5-14, ...	497.2	16.4	10,635	2,156	30.13	5,690	24.75	3,640
April 6-15, ...	496.9	15.0	10,532	2,122	29.91	5,812	26.84	3,573
April 7-16, ...	497.3	15.2	10,441	2,095	29.74	5,661	26.86	3,578
April 8-17, ...	496.5	13.4	10,264	2,062	29.17	5,267	26.15	3,646
April 9-18, ...	496.8	14.5	10,644	2,123	29.97	4,941	25.86	3,680
April 10-19, ...	497.0	14.0	10,552	2,104	29.68	4,731	25.44	3,627
April 11-20, ...	496.9	13.5	10,102	2,022	28.56	4,755	25.80	3,611
April 12-21, ...	496.9	13.4	9,926	1,974	27.90	4,499	25.10	3 644
April 13-22, ...	497.0	13.6	10,079	2,013	28.48	4,374	24.62	3 598
April 14-23, ...	497.2	13.7	10,076	2,015	28.49	4,245	23.68	3,589

Steer No. 3.

Nov. 26-Dec. 5, ...	427.1	19.3	....	....	....	....	....	....
Nov. 27-Dec. 6, ...	427.1	19.8	....	....	....	....	....	....
Nov. 28-Dec 7, ...	426.4	18.6	13,992	2,739	44.55	....	....	3,276
Nov. 29-Dec. 8, ...	426.4	19.1	13,652	2,669	42.55	6,198	49.59	3,347
Nov. 30-Dec. 9, ...	427.1	19.8	13,570	2,628	42.06	6,141	50.30	3,386
Dec. 1-10, ...	426.6	18.4	13,454	2,579	40.69	6,033	50.82	3,384
Dec. 2-11, ...	426.4	18.6	13,236	2,508	39.00	5,975	50.48	3,335
Dec. 3-12, ...	426.2	17.7	13,021	2,469	38.17	5,975	49.76	3,346
Dec. 4-13, ...	427.7	20.0	13,111	2,471	38.27	5,894	49.46	3,339
Dec. 5-14, ...	427.3	18.2	13,468	2,520	39.11	6,074	49.56	3,338
Dec. 6-15, ...	427.8	19.1	13,535	2,509	38.66	6,067	48.83	3,299
Dec. 7-16, ...	426.2	17.5	13,452	2,507	38.52	6,148	47.83	3,328
Dec. 8-17, ...	426.6	19.1	13,390	2,498	38.16	6,258	47.50	3,319

Steer No. 3—Continued.

	Live weight. Kgs.	Water drunk. Kgs.	Feces.			Urine.		Air-dry matter digested. Grams.
			Fresh weight. Grams.	Air-dry weight. Grams.	Nitrogen. Grams.	Weight. Grams.	Nitrogen. Grams.	
1894-5.								
Dec. 9-18, ...	426.8	19.3	13,530	2,528	38.64	6,173	46.60	3,270
Dec. 10-19, ...	426.9	18.6	13,326	2,489	37.31	6,067	46.18	3,281
Dec. 11-20, ...	427.8	19.3	13,311	2,489	37.34	5,969	45.04	3,307
Dec. 12-21, ...	428.4	19.3	13,440	2,528	37.94	5,917	44.82	3,342
Dec. 13-22, ...	428.0	19.6	13,538	2,558	38.34	5,985	45.30	3,356
Dec. 14-23, ...	427.8	18.8	13,636	2,587	38.57	6,022	45.36	3,287
Dec. 15-24, ...	428.7	20.0	13,417	2,557	37.99	5,971	44.95	3,282
Dec. 16-25, ...	428.2	18.4	13,292	2,548	37.86	6,151	44.75	3,316
Dec. 17-26, ...	429.8	20.7	13,396	2,531	37.19	6,221	44.52	3,302
Dec. 18-27, ...	429.6	18.6	13,424	2,551	37.46	6,338	44.22	3,336
Dec. 19-28, ...	429.4	18.6	13,287	2,531	37.26	6,400	43.36	3,388
Dec. 20-29, ...	428.9	18.2	13,193	2,560	37.54	6,417	42.12	3,432
Dec. 21-30, ...	428.7	17.9	12,932	2,550	37.49	6,475	41.89	3,470
Dec. 22-31, ...	427.8	17.3	12,720	2,522	37.25	6,415	41.53	3,469
Dec. 23-Jan. 1, ...	429.6	17.7	12,480	2,502	37.02	6,223	41.16	3,469
Dec. 24-Jan. 2, ...	430.0	17.4	12,293	2,473	36.50	5,991	41.19	3,431
Dec. 25-Jan. 3, ...	430.8	17.8	12,381	2,484	36.78	5,931	41.54	3,440
Dec. 26-Jan. 4, ...	431.7	18.0	12,507	2,494	36.74	5,868	42.07	3,448
Dec. 27-Jan. 5, ...	431.8	17.4	12,644	2,541	37.43	5,752	42.41	3,486
Dec. 28-Jan. 6, ...	432.9	18.1	12,640	2,530	37.04	5,895	43.31	3,444
Dec. 29-Jan. 7, ...	433.3	17.7	12,639	2,520	36.89	6,095	44.14	3,405
Dec. 30-Jan. 8, ...	433.9	18.0	12,543	2,481	36.35	6,288	44.82	3,382
Dec. 31-Jan. 9, ...	434.4	18.5	12,764	2,511	36.59	6,366	45.14	3,372
Jan. 1-10, ...	435.8	18.8	12,896	2,539	37.19	6,556	45.36	3,382
Jan. 2-11, ...	435.8	18.9	13,128	2,550	37.34	6,879	45.51	3,359
Jan. 3-12, ...	435.6	19.0	13,234	2,549	37.48	7,068	45.17	3,367
Jan. 4-13, ...	435.6	18.9	13,128	2,527	37.06	7,145	44.76	3,376
Jan. 5-14, ...	435.3	18.9	13,244	2,539	37.27	7,199	44.63	3,366
Jan. 6-15, ...	434.9	17.8	13,207	2,519	36.82	7,314	44.62	3,355
Jan. 7-16, ...	434.5	18.7	13,151	2,510	36.44	7,309	44.34	3,376
Jan. 8-17, ...	434.8	19.3	13,170	2,520	36.44	7,306	44.19	3,371
Jan. 9-18, ...	434.4	18.6	13,234	2,531	36.48	7,303	44.18	3,388
Jan. 10-19, ...	434.3	18.7	13,092	2,510	36.24	7,468	45.92	3,346
Jan. 11-20, ...	434.0	18.6	13,127	2,472	35.15	7,526	46.29	3,333
Jan. 12-21, ...	433.9	18.7	12,867	2,412	34.16	7,613	46.19	3,321
Jan. 13-22, ...	434.6	19.3	12,884	2,411	33.94	7,576	46.20	3,306
Jan. 14-23, ...	433.4	17.4	12,654	2,381	33.59	7,583	46.81	3,263
Jan. 15-24, ...	433.6	18.2	12,360	2,350	33.13	....	....	3,245
Jan. 16-25, ...	433.4	17.4	12,103	2,321	33.11	....	....	3,209
Jan. 17-26, ...	434.4	18.3	12,144	2,321	33.46	....	....	3,180
Jan. 18-27, ...	434.0	17.3	12,135	2,322	33.48	....	....	3,176
Jan. 19-28, ...	435.0	19.1	12,177	2,340	33.82	....	....	3,152
Jan. 20-29, ...	434.0	17.2	12,242	2,351	33.87	....	....	3,186
Jan. 21-30, ...	433.1	16.9	12,201	2,381	34.33	....	....	3,132
Jan. 22-31, ...	433.4	17.8	12,415	2,430	35.10	....	....	3,169
Jan. 23-Feb. 1, ...	433.3	17.2	12,466	2,421	35.40	....	....	3,204
Jan. 24-Feb. 2, ...	434.2	18.2	12,896	2,501	36.30	....	....	3,167
Jan. 25-Feb. 3, ...	433.9	17.5	12,932	2,504	36.48	....	....	3,210
Jan. 26-Feb. 4, ...	434.7	18.9	13,046	2,510	35.83	....	....	3,253
Jan. 27-Feb. 5, ...	434.2	18.0	13,283	2,588	36.54	....	....	3,264
Jan. 28-Feb. 6, ...	432.5	16.6	13,150	2,560	36.09	....	....	3,273
Jan. 29-Feb. 7, ...	432.1	17.4	12,958	2,532	35.58	....	....	3,291
Jan. 30-Feb. 8, ...	433.6	19.2	13,141	2,536	36.10	....	....	3,330
Jan. 31-Feb. 9, ...	435.5	19.7	13,247	2,542	36.46	....	....	3,372
Feb. 1-10, ...	434.9	17.8	13,273	2,536	36.31	7,280	45.53	3,368
Feb. 2-11, ...	436.2	20.2	13,335	2,509	35.66	7,160	45.43	3,395
Feb. 3-12, ...	436.3	19.6	13,225	2,479	35.14	7,107	45.91	3,435
Feb. 4-13, ...	437.2	20.4	13,370	2,480	35.21	6,844	46.40	3,359
Feb. 5-14, ...	436.5	20.0	13,425	2,450	35.50	6,824	47.21	3,379
Feb. 6-15, ...	436.6	20.5	13,552	2,407	35.31	6,572	46.55	3,411
Feb. 7-16, ...	438.0	22.1	....	....	....	....	....	....
Feb. 8-17, ...	437.7	20.8	....	....	....	....	....	....
Feb. 9-18, ...	437.1	20.7	....	....	....	....	....	....
Feb. 10-19, ...	434.2	18.5	....	....	....	....	....	....
Feb. 11-20, ...	434.1	21.1	....	....	....	....	....	....
Feb. 12-21, ...	432.2	18.8	....	....	....	....	....	....
Feb. 13-22, ...	432.6	20.6	....	....	....	....	....	....
Feb. 14-23, ...	431.5	18.8	....	....	....	....	....	....
Feb. 15-24, ...	432.5	19.8	....	....	....	....	....	....
Feb. 16-25, ...	431.9	18.0	....	....	....	....	....	....
Feb. 17-26, ...	431.5	17.7	....	....	....	....	....	....
Feb. 18-27, ...	432.4	18.4	....	....	....	....	....	....
Feb. 19-28, ...	432.8	17.6	....	....	....	....	....	....
Feb. 20, March 1, ..	434.6	19.1	....	....	....	....	....	....
Feb. 21-March 2, ..	435.7	18.4	....	....	....	....	....	....
Feb. 22-March 3, ..	435.5	17.2	....	....	....	....	....	....
Feb. 23-March 4, ..	434.8	16.5	....	....	....	....	....	....

Steer No. 3—Continued.

	Live weight. Kgs.	Water drunk. Kgs.	Feces.			Urine.		Air-dry matter digested. Grams.
			Fresh weight. Grams.	Air-dry weight. Grams.	Nitrogen. Grams.	Weight. Grams.	Nitrogen. Grams.	
1894-5.								
Feb. 24-March 5, ..	435.3	17.9	....	....	....	....	....	....
Feb. 25-March 6, ..	432.7	14.9	....	....	....	....	....	....
Feb. 26-March 7, ..	432.6	17.4	....	....	....	....	....	....
Feb. 27-March 8, ..	434.2	19.3	....	....	....	....	....	....
Feb. 28-March 9, ..	432.5	16.8	....	....	....	....	....	....
March 1-10, ...	432.0	17.9	....	....	....	....	....	....
March 2-11, ...	432.4	18.9	....	....	....	....	....	....
March 3-12, ...	430.9	16.8	....	....	....	....	....	....
March 4-13, ...	432.0	19.2	....	....	....	....	....	....
March 5-14, ...	431.5	17.8	....	....	....	....	....	....
March 6-15, ...	432.1	18.6	12,531	2,342	35.29	6,054	43.01	3,275
March 7-16, ...	433.4	19.2	12,542	2,342	35.12	5,874	41.75	3,341
March 8-17, ...	434.3	18.7	12,605	2,342	35.08	5,861	41.01	3,419
March 9-18, ...	433.5	16.5	12,266	2,288	34.64	5,883	39.71	3,483
March 10-19, ...	435.2	18.3	12,123	2,244	34.20	5,608	38.70	3,572
March 11-20, ...	435.9	17.1	11,974	2,199	33.87	5,635	38.47	3,680
March 12-21, ...	434.8	15.4	11,804	2,169	33.34	5,729	37.30	3,681
March 13-22, ...	435.5	16.9	11,632	2,113	33.33	5,601	35.51	3,723
March 14-23, ...	434.9	15.2	11,273	2,088	31.06	5,603	34.47	3,741
March 15-24, ...	435.1	16.1	11,362	2,020	30.83	5,584	33.79	3,677
March 16-25, ...	433.6	14.6	11,250	1,961	30.05	5,635	33.77	3,610
March 17-26, ...	434.1	16.5	11,195	1,926	29.49	5,487	33.60	3,527
March 18-27, ...	432.6	14.5	11,100	1,940	29.52	5,482	33.93	3,461
March 19-28, ...	431.6	15.4	11,291	1,957	29.57	5,403	34.06	3,421
March 20-29, ...	430.9	15.9	11,567	1,990	29.69	5,283	34.31	3,349
March 21-30, ...	430.7	16.2	11,616	2,006	29.39	5,106	33.89	3,321
March 22-31, ...	431.1	16.6	11,802	2,027	29.30	4,904	33.25	3,358
March 23-April 1, ..	431.0	16.4	12,110	2,080	29.73	4,854	32.59	3,329
March 24-April 2, ..	429.9	15.4	12,148	2,089	29.54	4,882	31.09	3,328
March 25-April 3, ..	429.3	15.5	12,013	2,083	29.19	4,777	29.43	3,354
March 26-April 4, ..	429.9	16.7	12,292	2,143	29.71	4,684	28.24	3,398
March 27-April 5, ..	429.7	16.1	12,413	2,174	29.72	4,786	27.54	3,427
March 28-April 6, ..	430.8	17.3	12,612	2,179	29.54	4,751	26.37	3,4[illegible]8
March 29-April 7, ..	431.7	17.2	12,578	2,177	29.16	4,674	25.54	3,467
March 30-April 8, ..	431.4	16.1	12,537	2,189	29.21	4,788	24.97	3,491
March 31-April 9, ..	431.1	16.4	12,583	2,199	29.37	4,963	24.62	3,492
April 1-10, ...	430.6	16.6	12,538	2,200	29.38	5,171	24.47	3,508
April 2-11, ...	428.4	14.9	12,296	2,187	28.97	5,271	24.34	3,538
April 3-12, ...	428.5	17.3	12,301	2,196	28.96	5,196	24.67	3,565
April 4-13, ...	429.2	17.8	12,287	2,190	28.97	5,100	24.86	3,558
April 5-14, ...	428.4	16.4	12,242	2,169	28.95	5,135	25.27	3,526
April 6-15, ...	428.2	16.8	12,160	2,140	28.61	5,047	24.95	3,564
April 7-16, ...	427.3	16.4	12 217	2,156	28.68	5,354	25.24	3,524
April 8-17, ...	426.8	17.1	12,330	2,176	28.72	5,463	24.85	3,508
April 9-18, ...	426.7	17.2	12,099	2,132	28.06	5,472	24.15	3,481
April 10-19, ...	426.6	17.2	12,232	2,158	28.17	5,489	23.50	3,458
April 11-20, ...	427.1	17.7	12,308	2,165	28.19	5,377	23.13	3,402
April 12-21, ...	429.0	19.0	12,471	2,173	28.35	5,270	22.59	3,445
April 13-22, ...	430.3	18.7	12,692	2,182	28.52	5,296	22.26	3,429
April 14-23, ...	429.9	17.5	12,964	2,224	28.87	5,430	22.46	3,38[illegible]

Experiments of 1896-7.

Date.	Daily Results.					
	Steer 1.		Steer 2.		Steer 3.	
	Live weight. Kgs.	Water drunk. Kgs.	Live weight. Kgs.	Water drunk. Kgs.	Live weight. Kgs.	Water drunk. Kgs.
October 18, 1896,	571.4	....	650.0	....	563.2	....
October 19, 1896,	558.0	0.0	639.0	0.0	548.2	0.0
October 20, 1896,	558.0	13.8	651.0	19.0	568.0	30.6
October 21, 1896,	559.1	16.4	636.3	0.0	578.0	16.2
October 22, 1896,	547.0	0.0	651.2	31.5	572.5	0.0
October 23, 1896,	555.0	21.4	635.0	0.2	566.6	0.0
October 24, 1896,	558.0	16.6	645.8	26.0	571.0	10.2
October 25, 1896,	545.0	0.0	634.0	0.0	581.0	18.2
October 26, 1896,	562.0	28.5	622.0	0.0	571.2	0.0
October 27, 1896,	549.0	0.0	638.4	30.6	557.0	0.0
October 28, 1896,	569.0	33.4	624.0	0.0	544.0	0.0
October 29, 1896,	555.0	0.0	650.0	41.0	546.0	29.0
October 30, 1896,	564.0	35.0	635.0	0.0	553.0	23.0
October 31, 1896,	549.0	0.0	650.0	30.0	535.0	0.0
November 1, 1896,	570.0	37.0	633.0	0.0	534.0	23.0
November 2, 1896,	554.0	0.0	643.0	25.0	513.0	0.0
November 3, 1896,	562.0	23.0	627.0	0.0	535.0	37.0
November 4, 1896,	556.0	12.0	612.0	0.0	517.0	0.0
November 5, 1896,	563.0	21.0	652.0	56.0	526.8	35.0
November 6, 1896,	563.4	16.0	635.4	0.0	509.6	0.0
November 7, 1896,	551.6	2.8	642.4	22.6	522.2	30.0
November 8, 1896,	567.0	31.0	646.6	13.6	506.0	2.8
November 9, 1896,	550.0	0.0	635.6	8.4	519.6	30.0
November 10, 1896,	561.2	26.1	621.0	0.0	502.0	0.0
November 11, 1897,	548.4	0.0	633.0	23.0	520.0	30.0
November 12, 1896,	559.6	23.6	627.0	0.0	506.0	0.0
November 13, 1896,	557.4	13.0	613.0	0.0	512.8	29.6
November 14, 1896,	551.2	8.6	643.0	41.0	497.0	0.0
November 15, 1896,	558.0	19.0	630.0	0.0	517.0	28.0
November 16, 1896,	542.0	0.0	637.0	21.0	500.8	0.0
November 17, 1896,	559.0	32.0	624.0	0.0	528.0	46.0
November 18, 1896,	542.0	1.0	640.6	31.0	505.0	0.0
November 19, 1896,	562.6	39.0	623.0	0.0	517.0	26.0
November 20, 1896,	547.4	0.0	626.0	16.0	503.0	4.0
November 21, 1896,	553.0	19.6	636.0	24.0	524.0	33.0
November 22, 1896,	548.0	10.0	623.0	0.0	509.0	0.0
November 23, 1896,	548.2	10.0	628.4	30.0	514.0	17.0
November 24, 1896,	545.0	8.0	619.0	0.0	504.0	4.8
November 25, 1896,	542.0	10.0	607.0	0.0	520.6	33.0
November 26, 1896,	541.0	11.0	636.0	40.0	506.0	0.0
Novemebr 27, 1896,	541.0	11.4	622.0	0.0	522.8	30.0
November 28, 1896,	537.0	5.4	611.0	0.0	509.0	0.0
November 29, 1896,	538.0	13.0	602.0	0.0	526.0	29.4
November 30, 1896,	528.6	0.0	622.0	30.0	513.0	0.0
December 1, 1896,	539.0	19.0	613.6	0.0	522.0	22.0
December 2, 1896,	531.0	0.0	605.0	0.0	509.2	0.0
December 3, 1896,	546.0	24.4	630.0	35.4	529.4	32.0
December 4, 1896,	531.4	0.0	619.2	0.0	518.0	0.0
December 5, 1896,	545.0	24.6	610.0	0.0	536.4	28.6
December 6, 1896,	536.0	0.0	632.6	31.0	525.0	3.4
December 7, 1896,	526.0	0.4	616.0	0.0	511.0	0.0
December 8, 1896,	555.0	43.0	609.0	0.0	535.0	37.0
December 9, 1896,	546.0	0.0	633.4	43.0	540.0	21.0
December 10, 1896,	542.0	7.0	622.0	0.0	524.2	0.6
December 11, 1896,	539.0	4.0	607.4	0.0	511.0	0.0
December 12, 1896,	556.2	27.6	624.0	28.0	534.8	36.0
December 13, 1896,	546.0	0.0	612.0	0.0	520.2	0.0
December 14, 1896,	543.0	9.0	621.0	20.8	534.0	29.8
December 15, 1896,	550.0	17.0	607.0	0.0	520.0	0.0
December 16, 1896,	541.0	1.8	632.0	35.8	510.6	0.8
December 17, 1896,	555.0	27.0	621.2	0.0	526.8	26.4
December 18, 1896,	541.0	0.0	621.0	13.0	516.6	0.0
December 19, 1896,	556.2	31.0	633.0	23.0	529.0	25.8
December 20, 1896,	544.2	0.0	620.0	0.0	516.6	0.0
December 21, 1896,	536.0	3.0	632.6	23.4	522.0	16.6
December 22, 1896,	557.0	30.2	623.0	0.0	512.0	1.6
December 23, 1896,	541.0	0.0	623.0	12.4	511.4	10.4
December 24, 1896,	551.0	24.0	612.0	0.0	523.0	21.2
December 25, 1896,	538.2	1.2	630.0	28.0	511.0	0.0
December 26, 1897,	545.0	22.8	619.0	0.0	515.4	16.0
December 27, 1896,	546.0	13.0	632.0	25.0	523.4	22.6
December 28, 1896,	533.4	0.0	621.4	0.0	513.0	0.0
December 29, 1896,	555.6	34.6	625.4	15.0	516.0	14.0
December 30, 1896,	541.0	0.0	625.0	10.0	505.0	0.0
December 31, 1896,	545.4	15.0	613.0	0.0	526.0	35.8
January 1, 1897,	536.0	2.0	634.0	33.0	514.0	0.0
January 2, 1897,	557.4	37.0	621.2	0.0	520.8	18.0
January 3, 1897,	544.0	0.0	626.0	17.4	506.4	0.0

Experiments—Continued.

Date.	Daily Results.					
	Steer 1.		Steer 2.		Steer 3.	
	Live weight. Kgs.	Water drunk. Kgs.	Live weight. Kgs.	Water drunk. Kgs.	Live weight. Kgs.	Water drunk. Kgs.
January 4, 1897,	537.0	6.0	614.0	0.0	529.0	38.6
January 5, 1897,	560.0	27.0	626.0	25.0	514.0	0.0
January 6, 1897,	545.2	0.0	616.0	0.0	527.0	32.0
January 7, 1897,	543.0	10.0	636.0	31.6	512.0	0.0
January 8, 1897,	552.0	18.0	622.0	0.0	501.0	0.0
January 9, 1897,	539.0	0.0	629.0	18.0	531.0	43.0
January 10, 1897,	548.0	19.0	628.8	12.0	518.0	0.0
January 11, 1897,	539.0	3.0	618.0	0.0	522.0	16.0
January 12, 1897,	540.0	9.6	631.0	23.0	514.2	6.0
January 13, 1897,	553.8	24.2	622.6	0.0	523.0	25.2
January 14, 1897,	544.0	0.0	629.2	17.8	512.0	0.0
January 15, 1897,	550.2	16.0	616.8	0.0	527.0	19.2
January 16, 1897,	540.0	0.0	631.8	24.6	517.4	0.0
January 17, 1897,	553.0	24.8	620.2	0.0	529.0	21.2
January 18, 1897,	544.6	0.0	629.0	21.2	518.2	0.0
January 19, 1897,	536.0	0.0	617.0	0.0	529.6	25.8
January 20, 1897,	554.0	26.0	632.0	25.2	518.0	1.4
January 21, 1897,	543.0	0.0	621.0	0.0	527.0	24.0
January 22, 1897,	544.0	11.0	611.0	0.0	514.2	0.0
January 23, 1897,	547.0	14.0	635.0	32.2	522.0	17.8
January 24, 1897,	537.0	0.0	623.0	0.0	513.0	1.0
January 25, 1897,	550.0	23.6	631.0	20.0	503.0	0.0
January 26, 1897,	540.0	0.0	621.0	0.0	528.0	34.0
January 27, 1897,	537.0	9.0	608.0	0.0	517.0	0.0
January 28, 1897,	534.8	9.4	630.8	33.0	506.0	0.0
January 29, 1897,	538.4	13.2	621.0	0.0	528.0	29.0
January 30, 1897,	537.6	10.6	632.0	25.0	514.0	0.0
January 31, 1897,	543.0	15.8	620.2	0.0	518.0	16.0
February 1, 1897,	532.6	2.0	633.2	26.8	506.4	0.0
February 2, 1897,	545.4	14.4	621.0	0.0	522.0	30.6
February 3, 1897,	532.4	0.0	634.0	26.4	511.0	3.0
February 4, 1897,	548.2	16.6	622.0	0.0	520.0	26.0
February 5, 1897,	536.4	0.0	645.6	36.0	506.0	0.0
February 6, 1897,	541.4	16.0	629.0	0.0	506.0	8.0
February 7, 1897,	543.0	11.0	637.2	18.0	526.6	34.6
February 8, 1897,	542.2	11.8	628.0	0.0	512.0	0.0
February 9, 1897,	544.0	12.8	639.0	29.0	520.6	23.0
February 10, 1897,	544.2	4.2	627.0	0.0	515.0	11.4
February 11, 1897,	541.6	10.2	647.0	33.6	512.0	12.0
February 12, 1897,	545.6	17.8	632.4	0.0	519.6	22.0
February 13, 1897,	540.0	6.4	643.4	24.2	510.0	6.4
February 14, 1897,	538.0	13.0	627.0	0.0	517.6	25.0
February 15, 1897,	542.0	15.0	630.0	12.0	504.0	0.0
February 16, 1897,	534.2	0.0	638.2	20.0	518.0	22.6
February 17, 1897,	541.0	17.2	627.0	0.0	514.0	7.0
February 18, 1897,	532.0	0.0	641.0	24.6	510.0	8.0
February 19, 1897,	545.2	22.0	629.0	0.0	523.0	26.4
February 20, 1897,	534.4	0.0	616.0	0.0	511.0	0.2
February 21, 1897,	544.0	20.6	642.2	35.4	512.6	14.0
February 22, 1897,	536.4	0.0	630.0	0.0	513.0	13.6
February 23, 1897,	548.6	21.0	633.0	14.0	518.0	16.0
February 24, 1897,	540.0	3.6	621.0	0.0	508.0	0.0
February 25, 1897,	543.0	12.6	643.0	34.4	515.0	17.0
February 26, 1897,	532.4	0.0	634.2	0.0	514.4	11.2
February 27, 1897,	543.0	21.6	630.6	13.4	521.0	17.6
February 28, 1897,	541.0	8.4	623.4	0.0	511.4	2.4
March 1, 1897,	545.4	11.4	640.2	27.8	521.2	24.8
March 2, 1897,	545.0	12.6	630.4	0.0	509.0	0.0
March 3, 1897,	536.2	0.0	617.6	0.0	521.2	25.0
March 4, 1897,	546.0	21.2	649.0	23.4	510.0	0.0
March 5, 1897,	554.0	0.0	639.0	0.0	522.6	23.6
March 6, 1897,	544.0	0.0	634.4	11.0	509.0	0.0
March 7, 1897,	549.0	16.0	637.0	12.6	518.0	21.0
March 8, 1897,	535.6	0.0	621.2	0.0	509.0	1.4
March 9, 1897,	543.2	18.4	632.4	20.8	514.4	15.2
March 10, 1897,	545.0	12.4	619.0	0.0	502.0	0.0
March 11, 1897,	532.2	0.0	632.0	28.2	524.0	35.4
March 12, 1897,	550.0	32.0	617.6	0.0	508.4	0.0
March 13, 1897,	534.4	11.4	646.8	42.0	523.6	31.6
March 14, 1897,	543.0	19.2	631.4	0.0	511.0	0.0
March 15, 1897,	543.4	13.0	634.6	15.2	502.0	0.6
March 16, 1897,	550.8	22.2	634.0	15.6	530.4	40.4
March 17, 1897,	537.6	1.8	633.0	16.0	511.0	0.0
March 18, 1897,	551.0	25.4	618.6	0.0	521.4	22.4
March 19, 1897,	541.0	6.4	634.0	36.4	512.0	6.6
March 20, 1897,	541.0	14.4	627.4	0.0	512.0	10.0
March 21, 1897,	542.0	17.0	637.0	25.0	524.0	30.0

Experiments—Continued.

Date.	Daily Results.					
	Steer 1.		Steer 2.		Steer 3.	
	Live weight. Kgs.	Water drunk. Kgs.	Live weight. Kgs.	Water drunk. Kgs.	Live weight. Kgs.	Water drunk. Kgs.
March 22, 1897,	540.0	13.8	631.0	0.0	510.0	0.6
March 23, 1897,	543.0	20.0	643.4	36.0	526.0	24.0
March 24, 1897,	540.6	13.0	627.6	0.0	508.4	0.0
March 25, 1897,	540.4	11.0	643.0	26.4	525.6	23.2
March 26, 1897,	542.0	17.2	628.4	0.0	511.0	0.0
March 27, 1897,	534.0	4.4	638.0	24.0	516.0	17.0
March 28, 1897,	547.0	32.0	631.2	8.6	515.0	14.6
March 29, 1897,	536.6	0.4	617.4	0.0	505.6	0.6
March 30, 1897,	528.6	3.6	635.0	28.2	523.0	27.0
March 31, 1897,	544.6	25.4	638.6	11.0	515.0	5.6
April 1, 1897,	535.0	0.0	635.0	11.4	505.0	0.0
April 2, 1897,	....	27.0	....	0.0	....	32.0

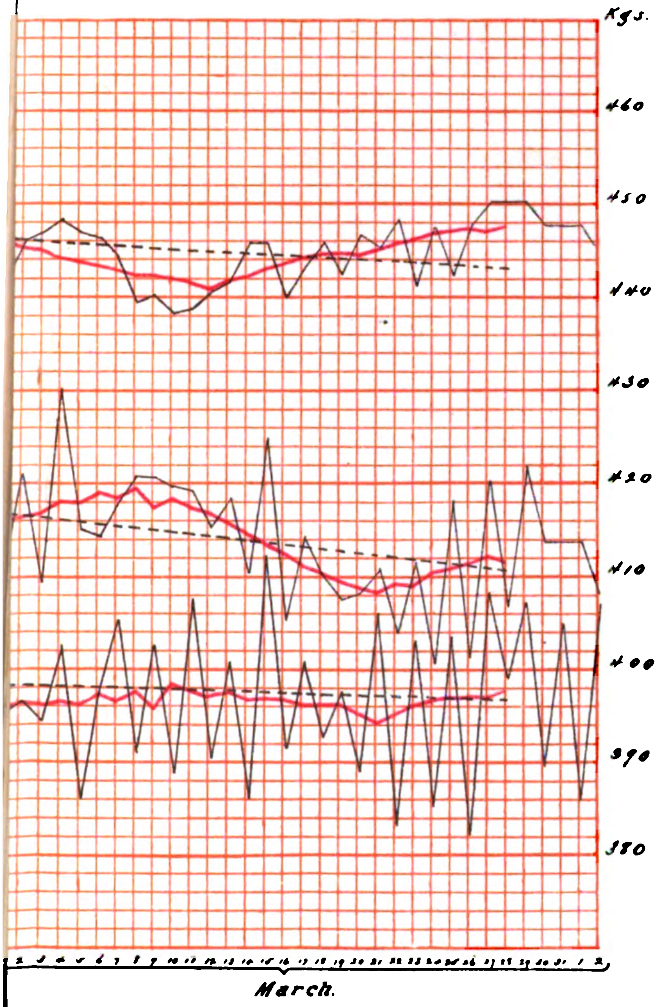
Experiments—Continued.

Date.	Ten-day Averages.					
	Steer 1.		Steer 2.		Steer 3.	
	Live weight. Kgs.	Water drunk. Kgs.	Live weight. Kgs.	Water drunk. Kgs.	Live weight. Kgs.	Water drunk. Kgs.
October 18-27, 1896,	556.2	....	640.3	....	567.6	....
October 19-28, 1896,	556.0	13.0	637.7	10.7	565.7	7.5
October 20-29, 1896,	555.7	13.0	638.8	14.8	565.5	10.4
October 21-30, 1896,	556.3	15.1	637.2	13.9	564.0	9.6
October 22-31, 1896,	555.3	13.4	638.5	15.9	559.7	8.0
October 23-November 1, 1896,	557.6	17.1	636.7	12.7	555.8	10.3
October 24-November 2, 1896,	557.5	15.0	637.5	15.2	550.5	10.3
October 25-November 3, 1896,	557.9	15.6	635.6	12.6	546.9	13.0
October 26-November 4, 1896,	559.0	16.8	633.4	12.6	540.5	11.2
October 27-November 5, 1896,	559.1	16.1	636.4	18.2	536.0	14.7
October 28-November 6, 1896,	560.5	17.7	636.1	16.2	531.3	14.7
October 29-November 7, 1896,	558.8	14.6	637.9	17.4	529.1	17.7
October 30-November 8, 1896,	560.0	17.7	637.2	14.7	525.1	15.0
October 31-November 9, 1896,	558.6	17.7	637.3	17.5	521.8	18.0
November 1-10, 1896,	559.8	16.8	634.4	12.56	518.5	15.7
November 2-11, 1896,	557.6	13.1	634.9	15.8	517.3	16.4
November 3-12, 1896,	558.2	15.5	633.3	13.3	516.6	16.4
November 4-13, 1896,	557.7	14.8	631.9	13.3	514.4	15.7
November 5-14, 1896,	557.2	14.2	635.0	17.4	512.2	15.7
November 6-15, 1896,	556.7	14.0	632.8	11.8	611.2	16.0
November 7-16, 1896,	554.6	14.0	632.9	13.9	510.3	16.0
November 8-17, 1896,	555.3	15.3	631.1	11.7	510.9	17.6
November 9-18, 1896,	552.8	12.3	630.9	13.4	510.8	17.3
November 10-19, 1896,	554.1	16.2	629.6	12.6	510.5	16.9
November 11-20, 1896,	552.7	13.6	630.1	14.2	510.6	17.3
November 12-21, 1896,	553.2	15.5	629.9	13.3	511.0	17.6
November 13-22, 1896,	552.0	14.2	629.5	13.3	511.3	17.6
November 14-23, 1896,	551.1	13.9	631.1	15.3	511.4	16.4
November 15-24, 1896,	550.5	13.8	628.7	11.2	512.1	16.8
November 16-25, 1896,	548.9	12.9	626.4	11.2	512.5	16.3
November 17-26, 1896,	548.8	14.0	626.3	13.1	513.0	16.8
November 18-27, 1896,	547.0	12.0	626.1	13.1	512.5	14.7
November 19-28, 1896,	546.5	12.4	623.1	10.0	512.9	14.8
November 20-29, 1896,	544.0	9.8	621.0	10.0	513.8	15.1
November 21-30, 1896,	542.1	9.8	620.6	11.4	514.8	14.7
November 22-December 1, 1896,	540.7	9.7	618.4	9.0	514.6	13.6
November 23-December 2, 1896,	539.0	8.7	616.6	9.0	514.6	13.6
November 24-December 3, 1896,	538.8	10.2	616.7	10.5	516.2	15.1
November 25-December 4, 1896,	537.5	9.4	616.7	10.5	517.6	14.6
November 26-December 5, 1896,	537.8	10.8	617.0	10.5	519.1	14.2
November 27-December 6, 1896,	537.3	9.7	616.7	9.6	521.0	14.5
November 28-December 7, 1896,	535.8	8.6	616.1	9.6	519.9	11.5
November 29-December 8, 1896,	537.6	12.4	615.9	9.6	522.5	15.2
November 30-December 9, 1896,	538.3	11.1	619.0	13.9	523.9	14.4
December 1-10, 1896,	539.6	11.8	619.0	10.9	525.0	15.0
December 2-11, 1896,	539.6	10.3	618.4	10.9	523.9	12.2
December 3-12, 1896,	542.1	13.1	620.0	13.7	526.4	15.8
December 4-13, 1896,	542.0	10.6	618.5	10.2	525.5	12.6
December 5-14, 1896,	543.2	11.5	618.7	12.2	527.1	15.6
December 6-15, 1896,	543.7	10.8	618.4	12.2	525.5	12.7
December 7-16, 1896,	544.2	10.9	618.3	12.7	524.0	12.5
December 8-17, 1896,	547.1	13.6	618.9	12.7	525.6	15.1
December 9-18, 1896,	545.7	9.3	620.1	14.0	523.8	11.4
December 10-19, 1896,	546.8	12.4	620.0	12.0	522.7	11.9
December 11-20, 1896,	547.0	11.7	619.8	12.0	521.7	11.8
December 12-21, 1896,	546.7	11.6	622.3	14.4	523.0	13.5
December 13-22, 1896,	546.8	11.9	622.2	11.6	520.7	10.1
December 14-23, 1896,	546.4	11.9	623.3	12.8	519.9	11.1
December 15-24, 1896,	548.2	13.4	622.4	10.7	518.8	10.2
December 16-25, 1896,	546.6	11.8	624.7	13.5	517.9	10.2
December 17-26, 1896,	546.4	13.9	623.4	9.9	518.3	11.8
December 18-27, 1896,	545.5	12.5	624.5	12.4	518.0	11.4
December 19-28, 1896,	544.8	12.5	624.6	11.1	517.6	11.4
December 20-29, 1896,	544.7	12.8	623.8	10.3	516.3	10.2
December 21-30, 1896,	544.4	12.8	624.1	11.3	515.2	10.2
December 22-31, 1896,	545.3	14.0	622.3	9.0	515.6	12.1
December 23-January 1, 1897,	543.2	11.2	623.4	12.3	515.8	12.0
December 24-January 2, 1897,	544.9	14.9	623.8	11.1	515.7	12.7
December 25-January 3, 1897,	544.2	12.5	624.7	12.8	515.1	10.6
December 26-January 4, 1897,	544.0	13.0	623.1	10.0	516.9	14.5
December 27-January 5, 1897,	545.5	14.4	623.8	12.5	516.7	12.9
December 28-January 6, 1897,	545.5	13.1	622.2	10.0	517.1	13.8
December 29-January 7, 1897,	546.4	14.1	623.6	13.1	517.0	13.3
December 30-January 8, 1897,	546.1	12.5	623.3	11.7	515.5	12.4
December 31-January 9, 1897,	544.9	12.5	623.7	12.5	518.1	16.7
January 1-10, 1897,	546.1	12.9	625.3	13.7	517.3	13.1
January 2-11, 1897,	546.4	13.0	623.7	10.4	518.1	14.7
January 3-12, 1897,	544.7	10.2	624'6	12.7	517.4	13.5

Experiments—Continued.

Date.	Ten-day Averages.					
	Steer 1.		Steer 2.		Steer 3.	
	Live weight. Kgs.	Water drunk. Kgs.	Live weight. Kgs.	Water drunk. Kgs.	Live weight. Kgs.	Water drunk. Kgs.
January 4-13, 1897,	545.7	12.6	624.3	10.9	519.1	16.0
January 5-14, 1897,	546.4	12.0	625.8	12.7	517.4	12.2
January 6-15, 1897,	545.4	9.9	624.9	10.2	518.7	14.1
January 7-16, 1897,	544.9	9.9	626.5	12.7	517.7	10.9
January 8-17, 1897,	545.9	11.4	624.9	9.5	519.4	13.0
January 9-18, 1897,	545.1	9.6	625.6	11.6	521.1	13.0
January 10-19, 1897,	544.8	9.6	624.4	9.8	521.0	11.3
January 11-20, 1897,	545.4	10.3	624.7	11.1	521.0	11.4
January 12-21, 1897,	545.8	10.0	625.0	11.1	521.5	12.2
January 13-22, 1897,	546.2	10.2	623.0	8.8	521.4	11.6
January 14-23, 1897,	545.5	9.1	624.3	12.1	521.4	10.9
January 15-24, 1897,	544.8	9.1	623.6	10.3	521.5	11.0
January 16-25, 1897,	544.8	10.9	625.1	12.3	519.1	9.2
January 17-26, 1897,	544.8	9.9	624.0	9.8	520.2	12.5
January 18-27, 1897,	543.2	8.3	622.8	9.8	519.0	10.4
January 19-28, 1897,	542.2	9.3	622.9	11.0	517.7	10.4
January 20-29, 1897,	542.5	10.6	623.3	11.0	517.5	10.7
January 21-30, 1897,	540.8	9.0	623.3	11.0	517.2	10.5
January 22-31, 1897,	540.8	10.6	623.3	11.0	516.3	9.7
January 23-February 1, 1897,	539.7	9.7	625.5	13.7	515.5	9.7
January 24-February 2, 1897,	539.5	9.7	624.1	10.4	515.5	11.0
January 25-February 3, 1897,	439.1	9.8	625.2	13.1	515.3	11.2
January 26-February 4, 1897,	538.9	9.1	624.3	11.1	517.0	13.8
January 27-February 5, 1897,	538.5	9.1	626.7	14.7	515.0	10.4
January 28-February 6, 1897,	539.0	9.8	628.8	14.7	513.9	11.2
January 29-February 7, 1897,	539.7	9.9	629.3	13.2	516.0	14.7
January 30-February 8, 1897,	540.2	9.8	630.2	13.2	514.4	16.2
January 31-February 9, 1897,	540.8	10.0	630.9	13.6	515.0	14.1
February 1-10, 1897,	540.9	8.8	631.6	13.6	514.7	13.6
February 2-11, 1897,	541.8	9.7	632.9	14.3	515.3	14.8
February 3-12, 1897,	541.9	10.0	634.1	14.3	515.0	14.0
February 4-13, 1897,	542.6	10.6	635.0	14.0	514.9	14.3
February 5-14, 1897,	541.6	10.3	635.5	14.0	514.7	14.2
February 6-15, 1897,	542.2	11.8	634.0	11.7	514.3	14.2
February 7-16, 1897,	541.4	10.2	634.9	13.7	515.5	15.7
February 8-17, 1897,	541.2	10.8	633.9	11.9	514.2	12.9
February 9-18, 1897,	540.2	9.6	635.2	14.4	514.0	13.7
February 10-19, 1897,	540.3	10.5	634.2	11.5	514.3	14.0
February 11-20, 1897,	539.4	10.1	633.1	11.5	513.9	12.9
February 12-21, 1897,	539.6	11.2	632.6	11.7	513.9	13.1
February 13-22, 1897,	538.7	9.4	632.3	11.7	513.3	12.3
February 14-23, 1897,	539.5	10.8	631.3	10.6	514.1	13.2
February 15-24, 1897,	539.7	9.9	630.7	10.7	513.1	10.7
February 16-25, 1897,	539.8	9.7	632.0	12.8	514.2	10.7
February 17-26, 1897,	539.7	9.7	631.6	10.8	513.9	11.3
February 18-27, 1897,	539.9	10.1	632.5	12.1	514.6	12.4
February 19-28, 1897,	540.8	10.1	630.7	12.1	514.7	12.4
February 20-March 1, 1897,	540.8	10.9	631.9	9.7	514.5	11.8
February 21-March 2, 1897,	541.8	9.9	633.3	11.5	514.3	11.6
February 22-March 3, 1897,	541.1	11.1	630.7	12.5	515.2	11.6
February 23-March 4, 1897,	542.0	11.2	632.7	12.3	514.9	11.4
February 24-March 5, 1897,	542.6	9.1	633.3	10.9	515.3	12.1
February 25-March 6, 1897,	543.0	8.7	634.7	12.0	515.4	12.1
February 26-March 7, 1897,	543.6	9.1	634.1	9.8	515.7	12.5
February 27-March 8, 1897,	543.9	9.1	632.8	9.8	515.2	11.5
February 28-March 9, 1897,	543.9	8.8	632.4	10.5	514.5	11.3
March 1-10, 1897,	544.3	9.2	632.0	10.5	513.6	11.1
March 2-11, 1897,	543.0	8.0	631.2	10.6	513.9	12.1
March 3-12, 1897,	543 5	10.0	629.9	10.6	513.8	12.1
March 4-13, 1897,	543.3	11.1	632.8	14.8	514.1	12.8
March 5-14, 1897,	543.0	10.9	631.0	11.4	514.2	12.8
March 6-15, 1897,	541.9	12.2	630.6	12.9	512.1	10.5
March 7-16, 1897,	512.6	14.4	630.6	13.4	514.2	14.5
March 8-17, 1897,	541.5	13.0	630.2	13.7	513.5	12.4
March 9-18, 1897,	543.0	15.5	629.9	13.7	514.8	14.5
March 10-19, 1897,	542.8	14.3	630.1	15.3	514.5	13.6
March 11-20, 1897,	542.4	14.5	630.9	15.3	515.5	14.6
March 12-21, 1897,	543.4	16.2	631.4	15.0	515.5	14.1
March 13-22, 1897,	542.4	14.4	631.7	15.0	515.7	14.1
March 14-23, 1897,	543.2	15.3	631.4	14.6	515.9	14.4
March 15-24, 1897,	543.0	12.7	631.0	14.6	515.7	14.4
March 16-25, 1897,	542.7	14.5	631.8	15.7	518.0	17.6
March 17-26, 1897,	541.9	14.0	631.2	14.1	516.1	13.6
March 18-27, 1897,	541.6	14.2	631.7	14.9	516.6	15.3
March 19-28, 1897,	541.2	14.9	633.0	15.8	516.0	14.6
March 20-29, 1897,	540.7	14.3	631.3	12.2	515.3	14.0
March 21-30, 1897,	539.5	13.2	632.1	15.0	516.4	15.7
March 22-31, 1897,	539.7	14.0	631.7	13.6	515.5	13.2
March 23,-April 1, 1897,	539.2	12.7	633.1	14.7	515.0	13.2
March 24-April 2, 1897,	....	13.4	....	10.9	....	13.0

Plate I.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